NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
AMES RESEARCH CENTER
MOFFETT FIELD, CALIFORNIA

STRATOSPHERIC OBSERVATORY FOR INFRARED ASTRONOMY (SOFIA)

SYSTEMS INTERFACE REQUIREMENTS

SPECIFICATION SOF-1030

ORIGINAL ISSUE AUGUST 1988

REVISION 3 MARCH 1996

REVISION 4 JUNE 2001

STRATOSPHERIC OBSERVATORY FOR INFRARED ASTRONOMY

SYSTEMS INTERFACE REQUIREMENTS

SPECIFICATION SOF-1030, REVISION 4

APPROVAL:

NASA/ARC SOFIA Project Manager — Date

DLR SOFIA Project Manager — Date

This document is a part of the SOFIA Project Documentation which is controlled by the SOFIA Project Office, NASA/Ames Research Center, Moffett Field, CA.

To be placed on the distribution list for controlled versions of this document, please address your request to:

SOFIA Project Manager, M.S. 244-30
NASA/Ames Research Center
Moffett Field, CA 94035-1000

REVISION HISTORY

(CHANGE RECORD)

STRATOSPHERIC OBSERVATORY FOR INFRARED ASTRONOMY

DOCUMENT TITLE: System Interface Requirements

DOCUMENT NO.: SOF-1030 **CONTROL NO.:** N/A

REV. NO.	DOCUMENT CHANGE REQUEST NUMBER	EFFECTIVE DATE	DESCRIPTION
3		Mar. 1996	
4	SOF-SCN-1030-001 DCR-0006, DCR-0007, DCR-0038.R1, DCR-0042, DCR-0044 SOF-SCN-1030-002 DCR-0012.R5, DCR-0046.R2, DCR-0054.R3, DCR-0107, DCR-0146	June 2000	

TABLE OF CONTENTS

		Page
1.0	SCOPE	1
1.1	PURPOSE	1
1.2	ELEMENT RESPONSIBILITIES	1
1.3	SOFIA OBJECTIVES	1
1.4	CONTENT STATUS	1
1.5	INTERFACE REQUIREMENTS CHANGE PROCEDURE/APPROVAL	2
2.0	APPLICABLE DOCUMENTS	2
2.1	ORDER OF PRECEDENCE	2
2.1.1	NASA/ARC Documents	2
2.1.2	Standards	2
2.1.3	Other Documents	2
3.0	GENERAL INTERFACE REQUIREMENTS	2
3.1	INTERFACE NUMBERING SCHEME	3
3.2	INTERFACE CONTROL DOCUMENTS	4
3.3	ICD RESPONSIBILITIES	4
3.4	ELEMENTS COMMON TO ALL INTERFACES	5
4.0	PERFORMANCE ASSURANCE	5
5.0	PREPARATION FOR DELIVERY, HANDLING, SHIPPING AND STORAGE	5
6.0	DELIVERABLES	5
7.0	RESPONSIBILITIES	5

TABLE OF CONTENTS (CONTD)

		Page
8.0	NOTES	6
8.1	DEFINITIONS	6
8.2	ABBREVIATIONS AND ACRONYMS	8
9.0	ENVIRONMENTS	11
9.1	AIRCRAFT MOTIONS/LOADS FOR AIRWORTHINESS EVALUATION	11
9.1.1	Quasi-static Translational Acceleration for Airworthiness Evaluation	11
9.1.2	Rotational Motions for Airworthiness Evaluation	17
9.2	AIRCRAFT MOTIONS/LOADS FOR TA PERFORMANCE EVALUATION	25
9.2.1	Translational Accelerations for TA Performance Evaluation	25
9.2.2	Rotational Motions for TA Performance Evaluation	32
9.2.3	Repeated Loads	39
9.2.4	Factors of Safety	47
9.3	DELETED	
9.4	WIND	48
9.5	CAVITY PRESSURE FLUCTUATION ENVIRONMENT	49
9.6	TORQUES IMPARTED TO TELESCOPE ASSEMBLY	50
9.7	TELESCOPE CAVITY TRANSIENT AIR ENVIRONMENT	59
9.7.1	Cavity Airborne Environment	59
9.7.2	Cavity Cool-down Environment	59
9.7.3	Cavity Re-heat Environment	59
9.8	AIRCRAFT CABIN AND CAVITY STEADY-STATE AIR ENVIRONMENT	63
9.8.1	Cabin and Cavity Steady-state Temperature	64
9.8.2	Cabin and Cavity Steady Pressure Environment	64

TABLE OF CONTENTS (CONTD)

		Page
9.9	ELECTROMAGNETIC INTERFERENCE (EMI) ENVIRONMENT	65
10.0	GLOBAL INTERFACES	67
10.1	INTRODUCTION	67
10.1.1	Master Interface Control Document (ICD) List	67
10.1.2	Airborne Facility Weight and Balance	67
10.1.3	SOFIA LAN Architecture	67
10.1.4	SOFIA Layout of Personnel Accommodations (LOPA)	68
10.1.5	SOFIA Coordinate Systems	68
10.1.6	Commercial Off-the-Shelf (COTS) Equipment	68
10.1.7	Aircraft Floor Loading Interface Requirements	69
10.1.8	Stray Light Control and Background Noise Suppression	69
10.1.9	Science Instrument Envelope	69
11.0	SYSTEM INTERFACES	70
11.1	TELESCOPE ASSEMBLY/AIRCRAFT SYSTEM INTERFACES	70
11.1.1	Aircraft Cavity Pressure Bulkhead/Telescope Assembly Interface	70
11.1.2	Aircraft Cavity Aft Bulkhead/Telescope Assembly Braking/Locking Subsystem Interface	71
11.1.3	Aircraft System/Telescope Assembly Cable Load Alleviation Device Interface	71
11.1.4	Aircraft System/Telescope Assembly Installation and Removal Interface	72
11.1.5	Aircraft Cavity/Telescope Optical Assembly Installation and Removal Interface Requirements	73
11.1.6	Aircraft Cavity ECS/Telescope Assembly Interface	73
11.1.7	Aircraft System/TA Rotation Isolation Subsystem Auxiliary Equipment Interface	74

TABLE OF CONTENTS (CONTD)

		Page
11.1.8	Aircraft System/Telescope Assembly Collimator Interface	74
11.1.9	Aircraft Cavity/Telescope Assembly Envelope	75
11.1.10	Aircraft Cabin/Telescope Assembly Envelope	75
11.1.11	Telescope Assembly/Aircraft System Exhaust Tube and Vacuum Line(s) Interface	76
11.1.12	Aircraft System/Telescope Assembly Power Interface	76
11.2	TELESCOPE ASSEMBLY/MISSION CONTROLS AND COMMUNICATIONS SYSTEM (MCCS)	76
11.2.1	Primary Mirror/Tertiary Mirror Electronics Subsystem/MCCS Interface	76
11.2.2	Thermal Control Subsystem/MCCS Interface	77
11.2.3	Secondary Mirror Control Subsystem/MCCS Interface	78
11.2.4	Rotational Drive Control Subsystem/MCCS Interface	78
11.2.5	Tracking Control Subsystem/MCCS Interface	79
11.2.6	Balancing Control Subsystem/MCCS Interface	80
11.2.7	Braking/Caging Control Subsystem/MCCS Interface	80
11.2.8	Pressure Window Control Subsystem/MCCS Interface	81
11.2.9	Rotation Isolation Control Subsystem/MCCS Interface	82
11.2.10	Vibration Isolation Control Subsystem/MCCS Interface	82
11.2.11	Pressure Seal/Compensator Control Subsystem/MCCS Interface	83
11.2.12	MCCS/Telescope Cable Distribution Interface	83
11.2.13	TA Video Subsystem/MCCS Interface	84
11.2.14	Telescope Assembly/MCCS Blind Pointing Interface	84
11.2.15	TA/MCCS Interface	85
11.3	TELESCOPE ASSEMBLY/SOFIA SCIENCE MISSION OPERATIONS (SSMO) INTERFACES	85

TABLE OF CONTENTS (CONTD)

		Page
11.3.1	SSMO GSF/Telescope Assembly Interfaces	85
11.3.2	SSMO Removal and Installation GSE/TA Optical Assemblies Handling Interface	86
11.3.3	SSMO Removal and Installation GSE/Telescope Subassembly Handling Interface	87
11.3.4	SSMO Ground Handling GSE/TA Optical Assemblies Interface	87
11.3.5	SSMO Ground Handling GSE/Telescope Subassembly Handling Interface	88
11.3.6	SSMO Mirror Processing Facility/TA Optical Assemblies Interface	88
11.3.7	Telescope Spider Assembly/SSMO Provided Spider Covers Mount Interface	88
11.3.8	Telescope Assembly/Baffle Plate Mount Interface	89
11.3.9	Telescope Secondary Mirror/SSMO Provided Secondary Mirror Button Mount Interface	89
11.3.10	TA Primary Mirror/SSMO Sun Filter Interface	89
11.3.11	TA Flange/SSMO GSE Telescope Flange Mockup Interface	90
11.3.12	SSMO-Supplied Secondary Mirror/Telescope Interface	90
11.3.13	SSMO-Supplied Tertiary Mirror/Telescope Interface	90
11.4	TELESCOPE ASSEMBLY/SCIENCE INSTRUMENT INTERFACES	91
11.4.1	Telescope Assembly Cable Load Alleviation Device/Science Instrument Cable Interface	91
11.4.2	Telescope Assembly/Science Instrument Mounting Interface	91
11.4.3	TA Attitude Control/Principal Investigator Computer Direct Digital Interface	91
11.4.4	TA Chopper Processor/Principal Investigator Computer Direct Analog Interface	92
11.5	AIRCRAFT SYSTEM/SCIENCE INSTRUMENT INTERFACES	92

TABLE OF CONTENTS (CONTD)

		Page
11.6	MCCS/SCIENCE INSTRUMENT INTERFACES	92
11.6.1	Principal Investigator Equipment Rack/PI Equipment Mounting Interface	92
11.6.2	Principal Investigator Computer/MCCS Interface	93
11.6.3	MCCS Patch Panel/SI Cable Interface	93
11.7	SOFIA SCIENCE AND MISSION OPERATIONS/SCIENCE INSTRUMENT INTERFACES	93
11.7.1	SSMO GSF/SI Requirements	93
11.7.2	SSMO TA Ground Simulator/Science Instrument Mount Interface	94
11.7.3	SSMO Cryogenic Supply/SI Interface	95

LIST OF FIGURES

Figure		Page
1A	Aircraft Ultimate and Emergency Landing Load Factors	15
1B	Aircraft Ultimate and Emergency Landing Load Factors at STA 1730 (B.A. 1570)	15
1C	Lateral Ultimate and Emergency Landing Load Factors (Aircraft Y Axis)	15
1D	Vertical Ultimate and Emergency Landing Load Factors (Aircraft Z Axis)	16
1E	Balance Arm to Body Station Conversions	17
1F	Quasi-Static Aircraft Limit Angular Rate and Acceleration Motions for Caged Telescope Loads	18
1G	Deleted	
1H	Aircraft Limit Roll Maneuver for Uncaged Telescope Loads	19
1I	Aircraft Limit Pitch Maneuver for Uncaged Telescope Loads	21
1J	Aircraft Limit Yaw Maneuver for Uncaged Telescope Loads	23
2B	Level 1 X-Direction Translational Accelerations	26
2C	Level 1 Y-Direction Translational Accelerations	27
2D	Level 1 Z-Direction Translational Accelerations	28
2E	Level 3 X-Direction Translational Acceleration	29
2F	Level 3 Y-Direction Translational Acceleration	30
2G	Level 3 Z-Direction Translational Acceleration	31
2I	Aircraft Roll Rotation - Telescope Operating Level 1	33
2J	Aircraft Pitch Rotation - Telescope Operating Level 1	34
2K	Aircraft Yaw Rotation - Telescope Operating Level 1	35
2L	Aircraft Roll Rotation - Telescope Operating Level 3	36
2M	Aircraft Pitch Rotation - Telescope Operating Level 3	37
2N	Aircraft Yaw Rotation - Telescope Operating Level 3	38

LIST OF FIGURES (CONTD)

Figure		Page
2O	Vertical Load Occurrences	40
2P	Lateral Load Occurrences	43
2Q	Axial Load Occurrences	43
2R	Normalized Time History Profile for Repeated Loads Worst-Case Vertical Acceleration at the Telescope Assembly Bulkhead	44
3A, B, C	Deleted	
4	Cavity Wind Environment – Mach Number Contours	48
5	Cavity Pressure Fluctuation Environment	49
6A	Dynamic Torques Imparted to Telescope Assembly Due to Pressure Fluctuations – TA Elevation Axis	51
6B	Dynamic Torques Imparted to Telescope Assembly Due to Pressure Fluctuations – TA Cross-Elevation Axis	52
6C	Dynamic Torques Imparted to Telescope Assembly Due to Pressure Fluctuations – TA LOS Axis	53
6D	Static Telescope Moments	54
6E	TA Pressure Areas	55
6F	TA Area and Centroid Position Information	57
7A	Cavity Air Environment – Airborne	60
7B	Cavity Air Environment – Cool-Down Environment	61
7C	Cavity Air Environment – Re-heat Environment	62
8A	Steady-state Temperature Environment (degrees C)	63
8B	Steady Pressure Environment (psia)	64
9A	Radiated EMI Environment – Cabin	65
9B	Radiated EMI Environment – Cavity	65
9C	Naturally Induced EMI Environment - Cabin	66
9D	Naturally Induced EMI Environment - Cavity	66

1.0 SCOPE

1.1 PURPOSE

This specification defines and controls the SOFIA systems interface requirements. The interface requirements consist of environments and hardware/software interfaces between separately developed systems (see Paragraph 1.2), defined herein as: the Aircraft System (AS), the Telescope Assembly (TA), the Mission Controls and Communications System (MCCS), the SOFIA Science and Mission Operations (SSMO), and the Science Instruments (SIs). A set of global interfaces are also specified. Global interfaces affect three or more of the system elements listed. All environments are defined and controlled within SOF-1030. Global Interfaces and hardware/software interfaces between systems are designated within separate sections of SOF-1030 and their detailed interfaces will be controlled by Interface Control Drawings (ICDs) referenced in those sections. The SOF-1030 document does not define the specifics of a particular interface. Separately controlled Interface Control Documents (ICDs) will be developed. Each ICD will contain all the information necessary to define an interface or set of interfaces. The purpose of SOF-1030 is to identify which interfaces must be controlled through an ICD, and which system element is responsible for developing the ICD. For each interface, SOF-1030 will also contain a list of items that may be, if applicable, included in the ICD controlling that interface.

1.2 ELEMENT RESPONSIBILITIES

This document specifies and controls interfaces between the system elements as defined herein, but not interfaces within each element. Therefore, the SOFIA Project Office (SPO) has developed hardware and associated software responsibilities for each system element, to allow definition of the baseline interface requirements. The system elements (AS, TA, MCCS, SSMO, and SI) are defined for interface control purposes based on developmental responsibilities, and this definition may differ from that appearing in other SOFIA specifications.

1.3 SOFIA OBJECTIVES

The SOFIA Facility will be a 2.5 meter, optical/infrared/sub-millimeter telescope mounted in a Boeing 747, to be used for many basic astronomical observations performed at stratospheric altitudes. The Facility will accommodate installation of different focal plane instruments, with in-flight accessibility, provided by investigators selected from the international science community. The Facility objective is to have an operational lifetime in excess of 20 years.

1.4 CONTENT STATUS

This specification delineates the interface and environment requirements for the SOFIA system elements given in Section 1.2 above. A "TBS" denotes a requirement or parameter to be supplied by the SPO; where a TBS is followed by a value in parentheses, this denotes a preliminary estimate. A "TBD" indicates a requirement or parameter to be determined by the appropriate contractor(s), with SPO approval. A TBD followed by a value in parentheses indicates a preliminary estimate of the value.

1.5 INTERFACE REQUIREMENTS CHANGE PROCEDURE/APPROVAL

Removal, additions, or changes of specifications and TBD/TBS values contained herein, may only be accomplished with SOFIA Project Office and DLR approval. Upon SOFIA Project Office and DLR acceptance of a proposed change, a proposed change notice will be transmitted to all affected parties for approval. Upon approval from all affected parties a change notice or specification revision will be generated.

2.0 APPLICABLE DOCUMENTS

The revision of the following documents in effect at the time of contract(s) initiation form a part of this requirement to the extent specified herein.

2.1 ORDER OF PRECEDENCE

The following documents may be used as reference.

2.1.1 NASA/ARC Documents

SOF-1010	SOFIA Aircraft System Requirements
SOF-1011	SOFIA Telescope Assembly Requirements
SOF-1012A	SOFIA Mission Support Facility – Integration and Test, FRD Work Package I
SOF-1012B	SOFIA Mission Support Facility – Operations, FRD Work Package II
SOF-1013	SOFIA Ground Support Equipment Requirements
SOF-1014	SOFIA Mission Control and Communications System Requirements
SOF-1090	SOFIA Investigators' Handbook

2.1.2 Standards

TBS

2.1.3 Other Documents

Code of Federal Regulations Title 14, Chapter 1, Part 25, Revision dated January 1, 1995 (FAR Part 25)

3.0 GENERAL INTERFACE REQUIREMENTS

Interface requirements are addressed herein by consolidating all the interfaces applicable to two major elements into a single section of this document; for example, all Aircraft System to Telescope Assembly interface requirements appear in Section 11.1. All Telescope Assembly to MCCS interface requirements appear in Section 11.2, and so forth.

3.1 INTERFACE NUMBERING SCHEME

All interfaces specified in this document are given a unique Interface Number (IN). This should not be confused with an Interface Control Document (ICD), which is described in the next section.

The IN given to a particular interface has the form:

AAA_BBB_NN

where 'AAA' refers to one of the system elements, and 'BBB' refers to the other system element involved in the interface. A number is appended ('NN') to distinguish the interface from others between the two system elements. For global interfaces, the numbering scheme is given as:

GLOBAL_NN

Below is a table which gives an example IN for each set of interfaces specified in this document.

GLOBAL_01	SOFIA Global interfaces
TA_AS_01	Telescope Assembly/Aircraft System interfaces
TA_MCCS_01	Telescope System/Mission Controls and Communications System interfaces
TA_SSMO_01	Telescope System/SOFIA Science and Mission Operations interfaces
TA_SI_01	Telescope System/Science Instrument interfaces
AS_SI_01	Aircraft System/Science Instrument interfaces
MCCS_SI_01	Mission Controls and Communications System/Science Instrument interfaces
SSMO_SI_01	SOFIA Science and Mission Operations/Science Instrument interfaces

Each interface is comprised of any number of sub-interfaces. When an interface is defined, a list of specific sub-interfaces is given with each interface description. The interface is defined in whole or in part by these sub-interfaces. Each of these sub-interfaces can be either physical, functional, or spatial. For example, the interface between the MCCS and the TA secondary mirror chopper control electronics contains both physical (mounting of the control electronics in the MCCS racks) and functional (data communication parameters) interfaces.

During the process of generating the ICDs, each of the system elements involved with a given interface shall be responsible for further definition and flow-down of the interfaces. The numbering scheme given above can be extended to delineate sub-interfaces which flow down from those referenced in SOF-1030. Extending the

example given in the last paragraph, the mounting interface for the control electronics could be denoted by TA_MCCS_01_P_01, and the communications interface could be denoted by TA_MCCS_01_F_01. In this example the P stands for a physical interface, and the F stands for a functional interface. The SOFIA Project Office will provide guidance in developing a flowdown numbering for interfaces, but it is left to the two system elements to reach agreement on the flowdown of interfaces.

3.2 INTERFACE CONTROL DOCUMENTS

The Interface Control Document (ICD) is the vehicle which will control the detailed requirements for a specific interface. The ICDs will be under configuration control by the SPO. The ICDs will be developed and controlled individually, separate from this document. SOF-1030 provides guidelines at the start of development for which interfaces are to be addressed in ICDs as well as what detailed items should be included in the ICDs. As the ICDs are developed they will supersede these guidelines.

One ICD may provide control for more than one IN. For example, consider the interface between the MCCS and the TA chopper mechanism control electronics, and the interface between the MCCS and the TA rotational isolation system control electronics. Each of these interfaces is given a unique IN. However, both of these interfaces may be controlled by the same ICD.

The contents of an ICD may take several forms. They may consist of a set of written requirements, a set of drawings, a computer model, or a combination of all three. The system elements involved with a particular interface will determine the best method to define that interface.

3.3 ICD RESPONSIBILITIES

For all interfaces, a lead system element will be identified. The responsibilities of the lead element on an interface definition are as follows:

(a) Coordinating the interface development process with all system elements involved with the interface.
(b) Generating the preliminary ICD which defines the given interface.
(c) Maintaining the documentation associated with the ICD.

There are responsibilities shared by all system elements involved in a given interface. These responsibilities are defined as follows:

(a) Supplying information necessary for the definition of an interface.
(b) Providing input to the scheduling and planning of interface definition.
(c) Reviewing the definition of interfaces.
(d) Approval of interface baselines and subsequent changes.
(e) Generation of change requests for ICDs when appropriate.
(f) For each interface, a verification plan shall be included as part of the associated ICD.

Except where noted for a given interface, the SPO and DLR will maintain a monitoring and review role during the initial development of an ICD. Once a baseline ICD is established, the SPO will have approval authority for changes to the ICD. Approvals shall be presumed granted for any submittal-for-approval not responded to by the SPO or DLR within 20 working days after submittal.

3.4 ELEMENTS COMMON TO ALL INTERFACES

The following items shall be included in each ICD which controls any of the interfaces defined in SOF-1030.

(a) For each interface, a detailed description of the specific responsibilities of both sides of the interface shall be included in the associated ICD.
(b) For each interface, a list of related INs, ICDs, and design drawings shall be included in the associated ICD.
(c) For each interface, a list of applicable environments shall be included in the associated ICD.
(d) For all mounting interfaces , the associated ICD shall include a detailed depiction of both sides of the attachment interface, including precise dimensions and tolerances.
(e) For ICDs between the TA and other assemblies, both SI (metric) and English units will be included for all dimensions and parameters.

4.0 PERFORMANCE ASSURANCE

Performance assurance requirements, including hardware safety, reliability, maintainability, quality assurance and software assurance requirements, are identified (or referenced) in documents SOF-1010, SOFIA Aircraft System Requirements; SOF-1011, SOFIA Telescope Assembly Requirements; SOF-1012, SOFIA Mission Support Facility Requirements; SOF-1013, SOFIA Ground Support Equipment Requirements; and SOF-1014, SOFIA Mission Controls and Communications System Requirements.

5.0 PREPARATION FOR DELIVERY, HANDLING, SHIPPING AND STORAGE

Preparation for delivery, handling, shipping and storage of the system elements shall be in accordance with the signed contract and Statement of Work (SOW).

6.0 DELIVERABLES

Hardware and software deliverables are specified in the Development Phase Contract Statements of Work (SOWs) for the system elements.

7.0 RESPONSIBILITIES

All system element development responsibilities are defined in SOF-1010 through -1014, and in the SOWs for each element. Interface responsibilities are defined herein.

8.0 NOTES

8.1 DEFINITIONS

Aircraft System (AS)
The AS consists of the modified SOFIA Aircraft, AS Airborne Support Equipment (AS ASE), and AS Ground Support Equipment (AS GSE).

Aircraft System Airborne Support Equipment (AS ASE)
The AS ASE is mission specific auxiliary equipment (e.g., electrical, mechanical, and environmental), used to characterize in-flight performance or perform other temporary functions in flight, such as additional pressure sensors and recording equipment used during flight testing.

Aircraft System Ground Support Equipment (AS GSE)
AS GSE is the GSE (e.g., electrical, mechanical, and environmental) employed in the integration, testing, and ground operations of the AS. GSE which is used during the SOFIA operational phase is designated as part of the Ground Support System. For the purposes of this document, any AS GSE which is developed and delivered by the AS contractor is considered part of the AS element.

Consoles and Electronics System (CES)
The CES element is no longer used and has been replaced by the MCCS.

Cross-Elevation Motion
TA motion in cross-elevation is motion about the TA V-axis, generally fore-aft motion with respect to the AS, and is orthogonal to TA elevation and LOS motion, centered on the spherical bearing. (This would be "yaw" motion if the TA were at 0° elevation).

Elevation Motion
TA motion in elevation is motion about the TA U-axis, similar to aircraft "roll" motion when their fore-aft axes are aligned.

Emergency Conditions
Emergency conditions are one of the three types of conditions (as defined herein) that may be encountered in SOFIA flight operations. Emergency conditions may exist when environments (e.g. accelerations) exceed certain limits, or when an emergency is declared by the flight crew. Emergency condition environments are specified in the "Environments" subsection of this document.

Flight Environments
Flight environments are the total set of environments (e.g., accelerations, thermal, pressure, etc.) which are present during SOFIA flight (including taxi, takeoff and landing), and under which the various observatory elements are required to function, transition to alternate status, or merely "survive". Flight conditions for which the environments apply include "operating", "non-operating", and emergency", as defined in detail herein.

Ground Support Equipment (GSE)
GSE consists of the equipment (including mechanical, electrical, optical, etc.) employed by the development and operations contractors in ground support of the observatory, and for integration and testing of the observatory elements. GSE which will be

employed during the SOFIA operational phase will be part of the Ground Support System, and may be provided by any system element. For purposes of this document, GSE is categorized with the system element that develops/delivers it.

Line-of-Sight (LOS) Motion
TA motion in LOS is rotation about the TA W-axis, centered at the spherical bearing, and orthogonal to motion in elevation and cross-elevation (this would be "pitch" rotation if the TA were at 0° elevation).

Mission Controls and Communications System (MCCS)
The MCCS provides user interface for control and monitoring SOFIA missions. It consists of the Mission Controls Subsystem (MCS), the Observatory Support Subsystem (OSS), the Ground Support System (GSS) Subsystems, and the Potential Upgrades System.

Non-Flight Environments
Non-flight environments are the total set of environments (e.g., temperature, humidity) to which the SOFIA Facility is exposed when not in flight (i.e., ground environments). Facility subsystems and components are required to function normally after exposure to these environments.

Non-Operating Conditions
Non-operating conditions are one of the three kinds of conditions that may be encountered in SOFIA operations. These conditions include flight and non-flight environments during periods when science observations are not being performed (e.g., takeoff, normal landing) or during periods when operating condition environments are exceeded, but short of emergency conditions, as defined herein.

Observatory
The SOFIA Observatory consists of the Aircraft System, the Telescope Assembly, Mission Controls and Communications Subsystem, and the Science Instrument(s).

Operating Conditions
Operating conditions are normally conditions in effect during flight including "door open" science observing operations, as limited by gust accelerations and other environmental parameters defined herein. Operating conditions may also be effective on the ground to allow system checkout and characterization.

Recovery Air Temperature
The cavity recovery air temperature is the average temperature of air in the cavity during operating conditions, i.e., after it has been "decelerated" and introduced into the cavity. This is normally 10-15° C higher than the outside air temperature, and a mean value of 235 K is expected. (This temperature increase does not include heating from warm surfaces in the cavity).

Science Instruments (SIs)
The Science Instruments are provided by the individual investigators for their observing flight series, and consist of focal plane assemblies (mounted to the Telescope Flange Assembly), support electronics installed in the aircraft cabin at investigator stations, and associated cabling, pneumatic lines, etc.

SOFIA Project Office (SPO)
The SPO is the government entity responsible for development of the SOFIA System, resident at NASA/ARC in the U.S.A.

SOFIA Science and Mission Operations (SSMO)
The SSMO consists of the Ground Support Facility (GSF) and Ground Support Equipment (GSE).

Subsystem
A subsystem is a combination of units, subassemblies, and parts, etc., which performs an operational function within a system and is a major subdivision of a system.

System
A system is a composite of equipment and techniques capable of performing or supporting an operational role or both. A complete system includes all equipment, facilities, material, software, services and skilled personnel required for its operation and support.

TBD (To Be Determined)
A "TBD" denotes a requirement to be determined by one or more system development contractors, with SOFIA Project Office approval. Where a TBD is followed by a value in parentheses, this denotes a preliminary value.

TBS (To Be Supplied)
A "TBS" denotes a requirement to be supplied by the SOFIA Project Office. Where a TBS is followed by a value in parentheses, this denotes a preliminary value.

Telescope Assembly (TA)
The Telescope Assembly is part of the overall Telescope System, and consists generally of the Telescope Optical Assembly, the Telescope Flange Assembly, and Supporting Structures, Mechanisms and Electronic and all associated software. Section 1.2 delineates the major components of the Telescope Assembly.

8.2 ABBREVIATIONS AND ACRONYMS

A	Ampere
AC	Alternating Current
A/D	Analog-to-Digital
ARC	Ames Research Center
AS	Aircraft System
ASE	Airborne Support Equipment
AZ	Azimuth
bps	Bits Per Second
CDR	Critical Design Review
CES	Consoles and Electronics System (replaced by MCCS)
c.g.	Center of Gravity

D/A	Digital-to-Analog
dB	Decibel
DC	Direct Current
DLR	Deutsches Zentrum fuer Luft-und Raumfahrt
DOF	Degree of Freedom
EL	Elevation
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
FAR	Federal Aviation Regulation
FFI	Fine Field Imager
FL	Flight Level
FOV	Field-of-View
FPI	Focal Plane Imager
FS	Factor of Safety
g	Acceleration of Earth's Gravity
GFE	Government Furnished Equipment
GSE	Ground Support Equipment
GSF	Ground Support Facility
GSS	Ground Support System
HVAC	Heating, Ventilation, and Air Conditioning
Hz	Hertz (cycles per second)
ICD	Interface Control Document
I.D.	Inner Diameter
IN	Interface Number
I/O	Input/Output
IR	Infrared
K	Degrees Kelvin
kbps	Kilobits per second
kg	Kilogram
km	Kilometer
kVA	Kilovolt-ampere
LAN	Local Area Network
LED	Light-emitting Diode
LOS	Line-of-Sight
m	Meters
mA	Milliamperes
MCCS	Mission Controls and Communications System (formerly CES)
MCS	Mission Control and Subsystem
MIL-STD	Military Standard
mm	Millimeter

MOU	Memorandum of Understanding
MTBF	Mean Time Between Failures
mW	Milliwatt
NASA	National Aeronautics and Space Administration
NHB	NASA Handbook
NM	Nautical Miles
NMI	NASA Management Instruction
NTSC	National Television Standards Committee
O.D.	Outside Diameter
PA	Procuring Activity
PDR	Preliminary Design Review
PSD	Power Spectral Density (Function)
RF	Radio Frequency
RH	Relative Humidity
RIS	Rotation Isolation Subsystem
RMS	Root-Mean-Square
ROF	Rotation of Field
RSS	Root-Sum-Square (square root of the sum of the squares)
SCFM	Standard Cubic Feet Per Minute
SI	Science Instrument
SLC	Shear Layer Control
SMA	Secondary Mirror Assembly
SOFIA	Stratospheric Observatory for Infrared Astronomy
SOW	Statement of Work
SPO	SOFIA Project Office
SSMO	SOFIA Science and Mission Operations
TA	Telescope Assembly
TBD	To Be Determined
TBS	To Be Supplied
TSY	Telescope System
UPS	Uninterruptible Power Supply
U. S. A.	United States of America
VIS	Vibration Isolation Subsystem
W	Watts
WAN	Wide Area Network
WBS	Work Breakdown Structure
WFI	Wide Field Imager

9.0 ENVIRONMENTS

9.1 AIRCRAFT MOTIONS/LOADS FOR AIRWORTHINESS EVALUATION

This section defines the critical loads cases essential to satisfy the requirements of FAR Part 25, primarily for the new equipment to be added, such as the Telescope Assembly and its components which are flight safety critical.

9.1.1 Quasi-static Translational Accelerations for Airworthiness Evaluation

This section presents the quasi-static load factors that shall be applied to the aircraft and all mounted equipment for ultimate, limit, and emergency landing conditions. All values are in g's, the acceleration of gravity. The axes coordinates given are in relation to the aircraft coordinate system.

The load factors should be interpreted as if a g-load of that magnitude is applied in the given direction to a piece of mounted equipment, relative to the aircraft. For example, a 0.2 g load factor on a piece of equipment in the forward direction (-X), would be equivalent to applying a force of 0.2(m)g to that piece of equipment in a direction towards the nose of the aircraft. The 'm' is the mass of the piece of equipment.

The following summarizes the critical load cases and how the loads should be combined. Subsequent paragraphs fully explain the cases.

Load Cases

Description	Combine Loads
Ultimate Cabin Pressure	2*p
Ultimate Aircraft - Vertical	U(z)
Ultimate Aircraft - Lateral or Axial	U(x, y) + 1.5*w
Ultimate Aircraft-Vert., and Cabin Pressure	U(z) + 1.5*p
Ultimate Aircraft-Lat./Axial, and Cabin P	U(x,y) + 1.5*w + 1.5*p
Limit Cabin Pressure	1.33*p
Limit Aircraft - Vertical	L(z)
Limit Aircraft - Lateral or Axial	L(x, y) + w
Limit Aircraft-Vert., and Cabin Pressure	L(z) + p
Limit Aircraft-Lat./Axial, and Cabin P	L(x,y) + w + p
Emergency Landing - Vertical	E(z)
Emergency Landing - Lateral	E(y)
Emergency Landing - Axial	E(x)

Load Definitions

Symbol	Description	Value
p	Cabin pressure relief valve setting (psi)	9.4
L(x, y, z)	Limit loads in the aircraft coordinate directions	Figures 1A, 1B, 1C, 1D Divided by 1.5
U(x, y, z)	Ultimate loads in the aircraft coordinate directions	Figures 1A, 1B, 1C, 1D
w	1.0g vertical load acting in downward (-Z) direction	weight of item (equipment or aircraft structure)
E(x, y, z)	Emergency Landing loads in the aircraft coordinate directions	Figures 1A, 1B, 1C, 1D

Notes:

1. On SOFIA, the reference coordinate system is placed at the nose (STA 90) of the 747SP with the positive x -axis towards the tail, the positive y-axis towards Right side (i.e. RBL, or right butt line), and the positive z-axis upwards (i.e. WL, or waterline). (Refer to Global_05)

2. The load factors in the above table give the magnitude and direction of external loads applied to the aircraft structure.

3. Load cases noted as "Aircraft" include Flight and Ground conditions as per FAR 25.

4. Sign conventions:

   Positive flight maneuvers produce a downward (-Z) g-load on the fuselage
   Negative flight maneuvers produce an upward (+Z) g-load on the fuselage
   Positive gust produces a downward (-Z) g-load on the fuselage
   Negative gust produces an upward (+Z) g-load on the fuselage

9.1.1.1 Aircraft Ultimate Loads - Figures 1A, 1B, 1C, and 1D give the maximum ultimate quasi-static load factors. Ultimate loads apply to all modifications of the aircraft and all equipment mounted in or on the aircraft, including the aircraft structure that supports it. Equipment or structural modifications may sustain detrimental permanent deformation when subjected to ultimate loads, but passenger access shall not be impeded and the stress caused by the ultimate load should be less than or equal to the ultimate strength of the particular material. The loads shall be applied to the TA operating in any of its modes, caged or uncaged, braked or unbraked, with the exception that the TA may be considered caged below 35,000 feet altitude. Ultimate loads for the vertical direction are applied independent of other directions. Ultimate loads for the lateral and axial directions must be combined with a 1.5 g vertical load.

Figure 1A shows load factors for various directions in the aircraft, and lists Figures 1C and 1D, which indicate load factors as a function of body arm coordinates and various operating conditions. Figures 1C and 1D should be read by taking the highest load operating condition for the applicable body balance arm position in the aircraft. Figure 1B provides load factors for STA 1730 where the bulkhead mounted TA components reside.

Figure 1E shows the relationship between 747SP balance arm coordinates and the body station coordinates.

All modifications of the aircraft and all equipment mounted in or on the aircraft shall be designed for:
1) Aircraft ultimate loads acting alone.
2) Aircraft ultimate loads acting in combination with a cabin pressure load equal to 1.5 times the maximum relief valve pressure differential (1.5 x 9.4 psi).
3) Ultimate pressure acting alone. Use an ultimate cabin pressure equal to (1.33x1.50) times the maximum relief valve pressure differential (1.33 x 1.50 x 9.4 = 18.8 psi).

9.1.1.2 Aircraft Limit Loads - limit loads apply to all modifications of the aircraft and all equipment mounted in or on the aircraft, including the aircraft structure that supports it. Equipment or structural modifications shall not sustain any detrimental permanent deformation when subjected to limit loads. At any load up to limit loads, the deformation may not interfere with safe aircraft operation. The stress caused by the limit load should be less than or equal to the yield strength of the particular material. Note that, as with the ultimate loads, the load factors for equipment or structure is dependent upon the aircraft station at which it is located. Also, as with the ultimate loads, the loads shall be applied to the TA operating in any of its modes, caged or uncaged, braked or unbraked, with the exception that the TA may be considered caged below 35,000 feet altitude. Limit loads for the vertical direction are applied independent of other directions. Limit loads for the lateral and axial directions must be combined with a 1.0 g vertical load. Maximum limit load factors may be derived by dividing the maximum ultimate load factors presented in Figures 1A, 1B, 1C, and 1D by 1.5.

All modifications of the aircraft and all equipment mounted in or on the aircraft shall be designed for:

1) Aircraft limit loads acting alone.
2) Aircraft limit loads acting in combination with cabin pressure loads equal to the maximum relief valve pressure differential (9.4 psi).
3) Limit pressure acting alone. Use a limit cabin pressure of 1.33 times the maximum relief valve pressure (1.33 x 9.4 = 12.5psi).

9.1.1.3 Emergency Landing Loads - Figure 1A, 1B, 1C, and 1D gives the aircraft emergency landing load factors. All supporting structure must be designed to restrain, under all loads up to those specified for an Emergency Landing, each item of mass that could injure an occupant if it came loose in a minor crash landing. Emergency landing loads are applied separately and independently in each direction. If necessary to meet this requirement, the TA may be assumed to be caged for this load condition.

Figure 1A. Aircraft Ultimate and Emergency Landing Load Factors

CONDITION	Lateral (±Y)	Fore (-X)	Aft (+X)	Up (+Z)	Down (-Z)
Aircraft Ultimate Loads	Figure 1C	1.60	1.50	Figure 1D	Figure 1D
Emergency Landing Loads	Note ***	9.00	1.50	3.00	6.00

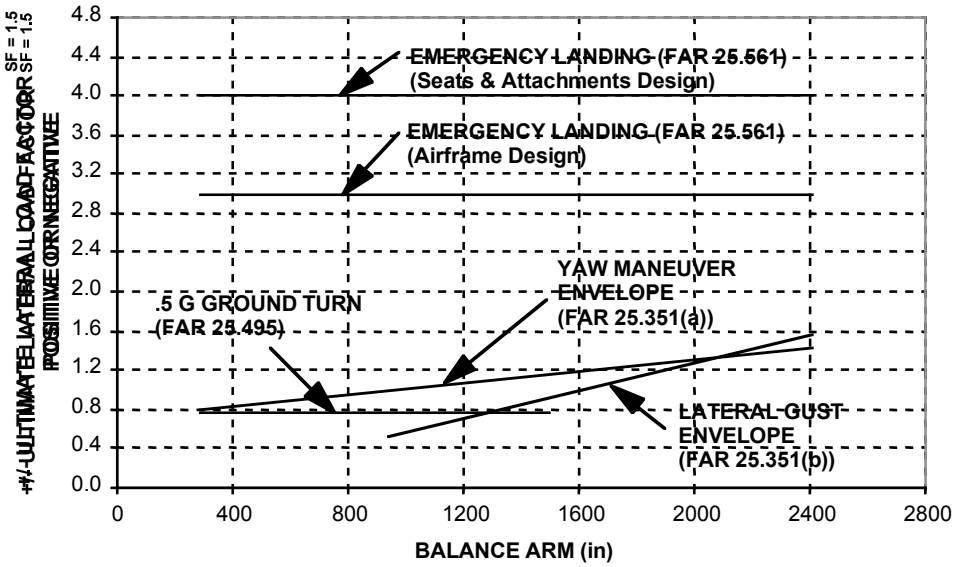
*** 3.00 g on the airframe and 4.00 g on the seats and their attachments.

Figure 1B. Aircraft Ultimate and Emergency Landing Load Factors at STA 1730 (B.A. 1570)

CONDITION	Lateral (±Y)	Fore (-X)	Aft (+X)	Up (+Z)	Down (-Z)
Aircraft Ultimate Loads	1.17	1.60	1.50	1.95	4.93
Emergency Landing Loads	3.00	9.00	1.50	3.00	6.00

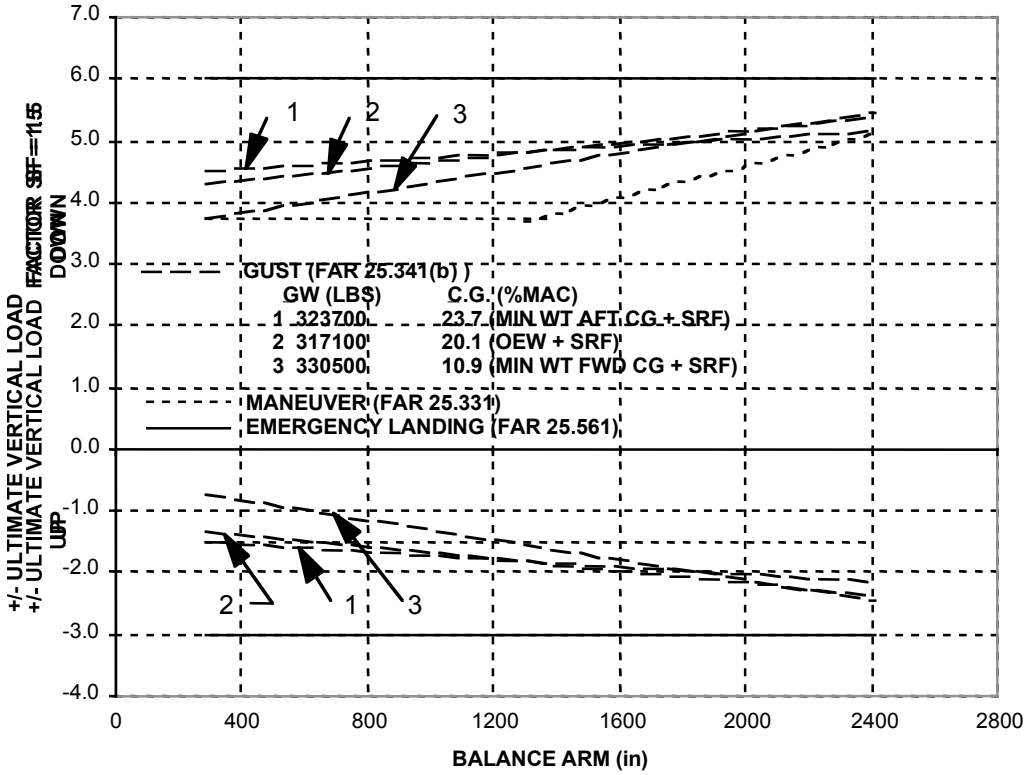
Note: Use Figure 1B for TA equipment mounted to the Forward Pressure Bulkhead at STA 1730.

Figure 1C. Lateral Ultimate and Emergency Landing Load Factors (Aircraft Y Axis)



Note: Figure 1E shows the relationship between 747SP balance arm coordinates and body station coordinates.

Figure 1D. Vertical Ultimate and Emergency Landing Load Factors (Aircraft Z Axis)



Notes: 1. Figure 1E shows the relationship between 747SP balance arm coordinates and body station coordinates.

2. The flight loads in Figure 1D already includes the effects of aircraft rigid body rotation and may be applied directly. When applying loads to components mounted in the aircraft, use the worse case of the values shown for the maneuver condition and three gust conditions, for the applicable aircraft balance arm locations.

3. Note:
GW: Gross Weight
MAC: Mean Aerodynamic Chord
SRF: Structural Reserve Fuel
OEW: Operator Empty Weight

Figure 1E. Balance Arm to Body Station Conversions

Balance Arms have the following relationship with Body Stations:

BODY STATION (STA) (inches)	ADJUSTMENT (inches)	BALANCE ARM (inches)
90 to 800	+200	290 to 1000
800 to 1000	----	section removed
1000 to 1480	0	1000 to 1480
1480 to 1640	----	section removed
1640 to 2140	-160	1480 to 1980
2140 to 2360	----	section removed
2360 to 2792	-380	1980 to 2412

9.1.2 Rotational Motions for Airworthiness Evaluation

This section presents the aircraft rotational motions that must be applied to components to evaluate airworthiness. Translational loads shall be superimposed as described in Figures 1F, 1I, and 1J.

SOFIA will have a telescope assembly (TA) which, above 35,000 feet altitude, can be uncaged (or unbraked) and allowed to rotate freely, relative to the aircraft, ± 3 degrees in the roll, pitch, and yaw directions. The aircraft c.g., for the purpose of time history analysis of rotational motions, is at STA 1285 (balance arm 1285). This results in a lever arm of u=7239mm (285 in.) from the aircraft c.g. to STA 1730 (BA 1570).

Below 35,000 feet the TA will always be caged and will be subjected to maximum aircraft rotational rates and accelerations as shown in Figure 1F. For roll motions, two load cases for Nz have to be considered.

Figures 1H, 1I, and 1J are time histories of aircraft limit maneuvers for roll, pitch, and yaw respectively, at 35,000 feet and above. All given Nz values are in –z direction (down).

Figure 1H shows the roll angle (phi), roll rate (P), and roll acceleration (P dot) developing after a combined maximum aileron and spoiler input. The beginning of the most severe snubbing condition for the TA within ± 3 degrees free rotation range occurs after a travel of 6 degrees.

Figure 1I shows pitch angle (delta theta), pitch rate (Q), pitch acceleration (QDOT), and aircraft c.g. Nz developing with time for a checked elevator maneuver (nose up).

Figure 1J shows yaw angle (Beta), yaw rate (R), and yaw acceleration (R dot), and aircraft c.g. Ny developing with time for a maximum rudder input. For evaluating loads on the telescope assembly (TA), most of which must rotate in TA elevation through a large range (15 to 70 degrees), use the pitch limit maneuvers as the worse case about both the TA Cross Elevation axis and the TA Line of Sight axis.

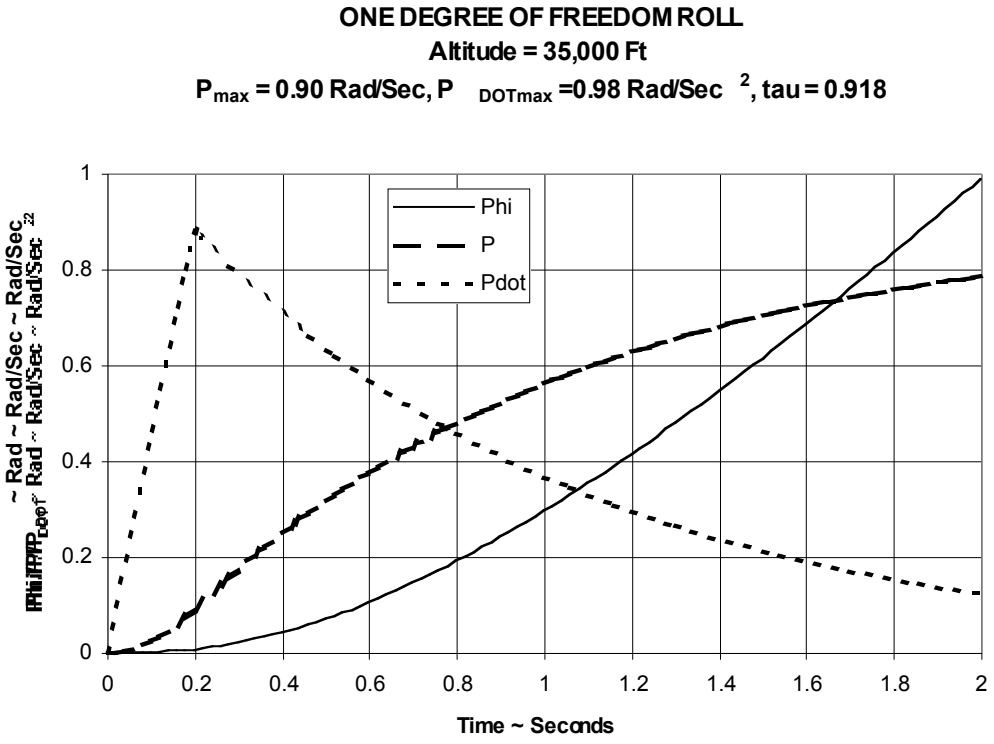
Figure 1F
Quasi-Static Aircraft Limit Angular Rate and Acceleration Motions for Caged Telescope Loads

Aircraft Limit Angular Motion			Associated Limit Acceleration At Telescope Center of Gravity
Parameter	Variable Name (Units)	Value	
Positive Roll Rate	P_{MAX} (Rad/Sec)	1.08	Nz = 0.00 (repeat with Nz = 1.67)
Negative Roll Rate	P_{MIN} (Rad/Sec)	-1.08	Nz = 0.00 (repeat with Nz = 1.67)
Positive Roll Acceleration	P_{DOTMAX} (Rad/Sec^2)	1.48	Nz = 0.00 (repeat with Nz = 1.67)
Negative Roll Acceleration	P_{DOTMIN} (Rad/Sec^2)	-1.48	Nz = 0.00 (repeat with Nz = 1.67)
Positive Pitch Rate	Q_{MAX} (Rad/Sec)	1.05	Nz = 2.37
Negative Pitch Rate	Q_{MIN} (Rad/Sec)	-1.05	Nz = -1.13
Positive Pitch Acceleration	Q_{DOTMAX} (Rad/Sec^2)	0.51	Nz = -1.30
Negative Pitch Acceleration	Q_{DOTMIN} (Rad/Sec^2)	-0.51	Nz = 2.70
Positive Yaw Rate	R_{MAX} (Rad/Sec)	0.52	Ny = -0.29 and Nz = 1.00
Negative Yaw Rate	R_{MIN} (Rad/Sec)	-0.52	Ny = 0.29 and Nz = 1.00
Positive Yaw Acceleration	R_{DOTMAX} (Rad/Sec^2)	0.34	Ny = 0.49 and Nz = 1.00
Negative Yaw Acceleration	R_{DOTMIN} (Rad/Sec^2)	-0.34	Ny = -0.49 and Nz = 1.00

Note: Figure 1F applies only to TA components mounted on the pressure bulkhead.

Figure 1G
(deleted)

Figure 1H
Aircraft Limit Roll Maneuver for Uncaged Telescope Loads



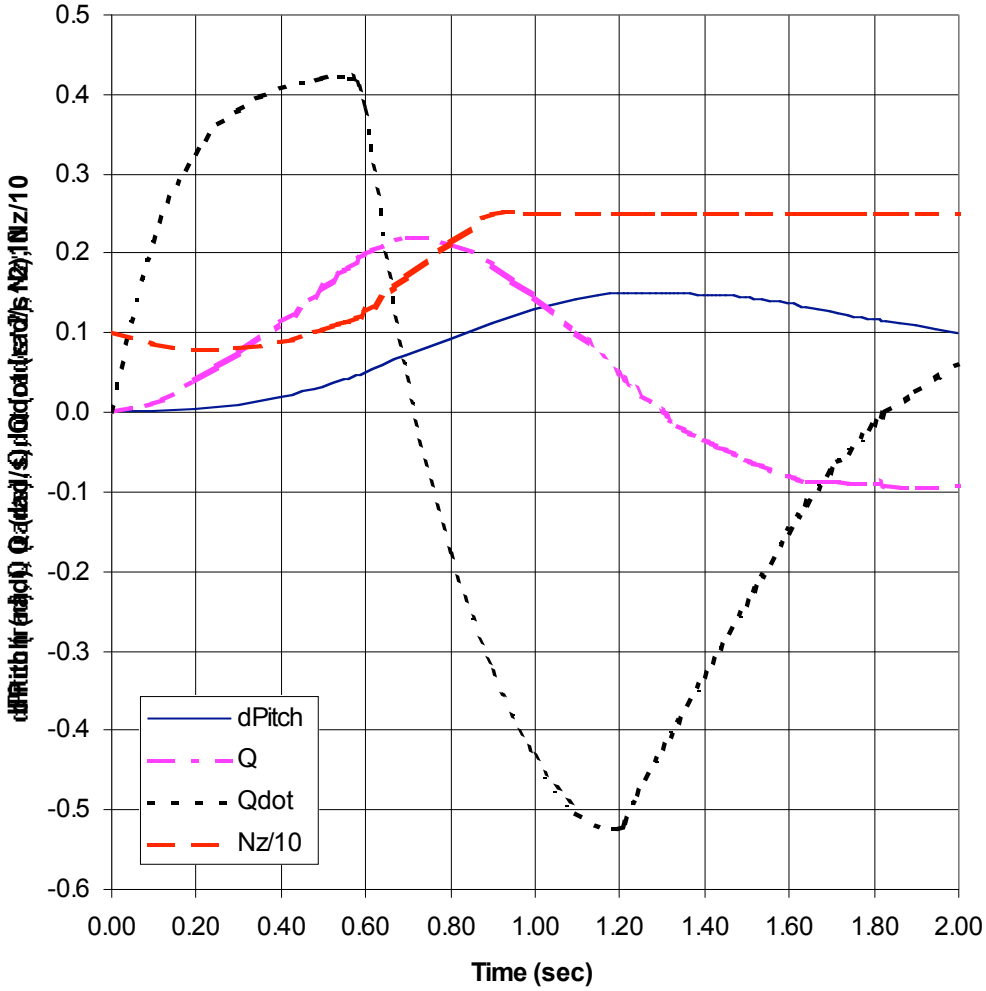
Note: This roll motion must be combined with a constant linear load of Nz=0 and Nz=1.67 in separate load cases.

ONE DEGREE OF FREEDOM ROLL
Altitude = 35,000 Ft

P_{max} = 0.90 Rad/Sec, P_{DOTmax} =0.98 Rad/Sec^2, tau = 0.918

Time (Seconds)	Phi (Deg)	Phi (Rad)	P (Rad/Sec)	P_{DOT} (Rad/Sec^2)
0.000	0.000	0.000	0.000	0.000
0.100	0.046	0.001	0.024	0.464
0.200	0.356	0.006	0.091	0.881
0.300	1.123	0.020	0.175	0.790
0.400	2.342	0.041	0.250	0.708
0.500	3.967	0.069	0.317	0.635
0.600	5.956	0.104	0.377	0.570
0.700	8.273	0.144	0.431	0.511
0.800	10.882	0.190	0.479	0.458
0.900	13.754	0.240	0.523	0.411
1.000	16.862	0.294	0.562	0.369
1.100	20.181	0.352	0.596	0.331
1.200	23.690	0.413	0.628	0.296
1.300	27.369	0.478	0.656	0.266
1.400	31.200	0.545	0.681	0.238
1.500	35.180	0.614	0.704	0.214
1.600	39.248	0.685	0.724	0.192
1.700	43.487	0.759	0.742	0.172
1.800	47.785	0.834	0.758	0.154
1.900	52.139	0.910	0.773	0.138
2.000	56.608	0.988	0.786	0.124

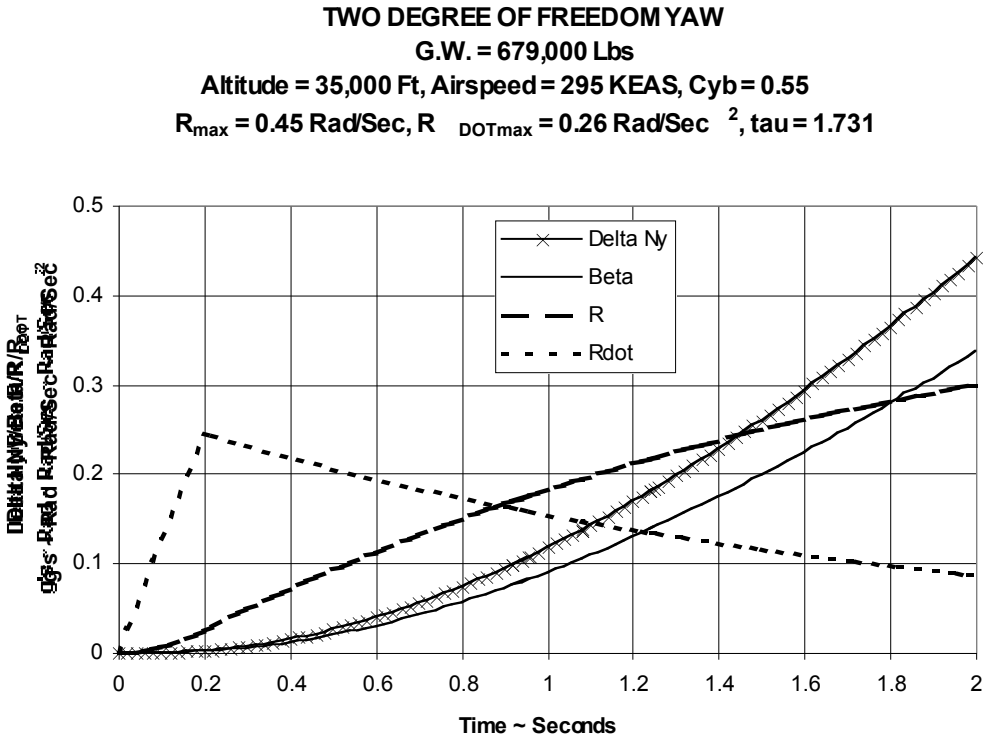
Figure 1l
Aircraft Limit Pitch Maneuver for Uncaged Telescope Loads



Time (sec)	dPitch (deg)	dPitch (rad)	Q (rad/s)	Qdot (rad/s^2)	Nz
0.000	0.00	0.000	0.000	0.000	1.00
0.100	0.02	0.000	0.011	0.214	0.86
0.200	0.16	0.003	0.039	0.327	0.79
0.300	0.49	0.009	0.075	0.380	0.81
0.400	1.03	0.018	0.114	0.408	0.89
0.500	1.80	0.031	0.156	0.420	1.03
0.540	2.18	0.038	0.173	0.421	1.10
0.560	2.38	0.042	0.181	0.419	1.14
0.580	2.59	0.045	0.189	0.415	1.18
0.600	2.81	0.049	0.198	0.380	1.25
0.700	4.02	0.070	0.219	0.044	1.72
0.800	5.26	0.092	0.210	-0.179	2.14
0.900	6.40	0.112	0.185	-0.327	2.48
1.000	7.35	0.128	0.147	-0.434	2.50
1.100	8.06	0.141	0.100	-0.504	2.50
1.200	8.48	0.148	0.047	-0.525	2.50
1.240	8.57	0.150	0.027	-0.480	2.50
1.300	8.54	0.149	0.000	-0.425	2.50
1.340	8.54	0.149	-0.018	-0.389	2.50
1.400	8.42	0.147	-0.034	-0.334	2.50
1.440	8.31	0.145	-0.044	-0.297	2.50
1.500	8.19	0.143	-0.059	-0.242	2.50
1.520	8.14	0.142	-0.064	-0.224	2.50
1.600	7.73	0.135	-0.079	-0.151	2.50
1.640	7.51	0.131	-0.087	-0.115	2.50
1.700	7.22	0.126	-0.088	-0.075	2.50
1.740	6.99	0.122	-0.089	-0.049	2.50
1.800	6.70	0.117	-0.091	-0.016	2.50
1.830	6.53	0.114	-0.092	0.000	2.50
1.900	6.19	0.108	-0.096	0.025	2.50
2.000	5.61	0.098	-0.093	0.060	2.50

Figure 1J

Aircraft Limit Yaw Maneuver for Uncaged Telescope Loads



TWO DEGREE OF FREEDOM YAW
G.W. = 679,000 Lbs
Altitude = 35,000 Ft, Airspeed = 295 KEAS, Cyb = 0.55
R_{max}= 0.45 Rad/Sec, R_{DOTmax}= 0.26 Rad/Sec^2, tau = 1.731

Time (Seconds)	Delta Ny	Beta (Deg)	Beta (Rad)	R (Rad/Sec)	R_{DOT} (Rad/Sec^2)
0.000	0.000	0.000	0.000	0.000	0.000
0.100	0.000	0.012	0.000	0.006	0.126
0.200	0.002	0.097	0.002	0.025	0.246
0.300	0.007	0.309	0.005	0.049	0.232
0.400	0.015	0.655	0.011	0.071	0.219
0.500	0.026	1.125	0.020	0.093	0.206
0.600	0.039	1.714	0.030	0.113	0.195
0.700	0.055	2.415	0.042	0.132	0.184
0.800	0.074	3.221	0.056	0.150	0.174
0.900	0.094	4.126	0.072	0.166	0.164
1.000	0.117	5.126	0.089	0.182	0.155
1.100	0.142	6.214	0.108	0.197	0.146
1.200	0.169	7.385	0.129	0.212	0.138
1.240	0.181	7.907	0.138	0.217	0.135
1.300	0.198	8.636	0.151	0.225	0.130
1.400	0.228	9.961	0.174	0.238	0.123
1.440	0.245	10.485	0.183	0.243	0.123
1.500	0.266	11.345	0.198	0.250	0.117
1.520	0.273	11.631	0.203	0.253	0.116
1.600	0.301	12.777	0.223	0.262	0.111
1.640	0.315	13.350	0.233	0.267	0.109
1.700	0.336	14.267	0.249	0.273	0.105
1.740	0.350	14.897	0.260	0.278	0.102
1.800	0.371	15.814	0.276	0.284	0.097
1.830	0.382	16.329	0.285	0.287	0.095
1.900	0.406	17.475	0.305	0.294	0.088
2.000	0.441	19.137	0.334	0.303	0.082

9.2 AIRCRAFT MOTIONS/LOADS FOR TA PERFORMANCE EVALUATION

The following translational and rotational aircraft motions shall be applied to the TA system for the purpose of evaluating required TA performance. The three motion levels are:

1. Operating Level 1: These are maximum flight conditions for which the TA must fully operate, maintain tracking, and meet all of its performance requirements, including pointing stability and image quality. On the ground, the TA must fully operate, maintain tracking, but is allowed to meet degraded pointing stability and image quality requirements.

2. Operating Level 2: These are maximum flight conditions for which, as a goal, the TA will fully operate, maintain tracking, and meet all of its performance requirements, including pointing stability and image quality.

3. Telescope operating Level 3: These are ground conditions for a stationary aircraft (no taxiing or towing) and for which the TA must fully operate and track astronomical objects, but allowed to meet a degraded pointing stability and image quality requirement.

9.2.1 Translational Accelerations for TA Performance Evaluation

All accelerations apply to STA 1730. Loads in this section do not include the steady-state 1 g of Earth's gravity.

Time histories for these dynamic loads are shown in Figures 2B through 2G. Figures 2B, 2C, & 2D show aircraft translational acceleration time histories and their resulting power spectral density functions (PSDs) with cumulative RMS values, for telescope operating level 1 conditions. The actual electronic file of the time histories is provided separately from this document. The file name is accelLevel1.txt and is located on NASA server jean-luc.arc.nasa.gov in /user/people/mcintyre/flight_test. The aircraft translational acceleration time histories for telescope operating level 2 conditions can be taken as twice the values that are provided in the level 1 time histories. Figures 2E, F, & G are charts of aircraft translational acceleration time histories and their resulting PSDs with cumulative RMS values, for telescope operating level 3 conditions, and its electronic file is named accelLevel3.txt located on the same NASA server.

Figure 2B - Level 1 X-Direction Translational Accelerations

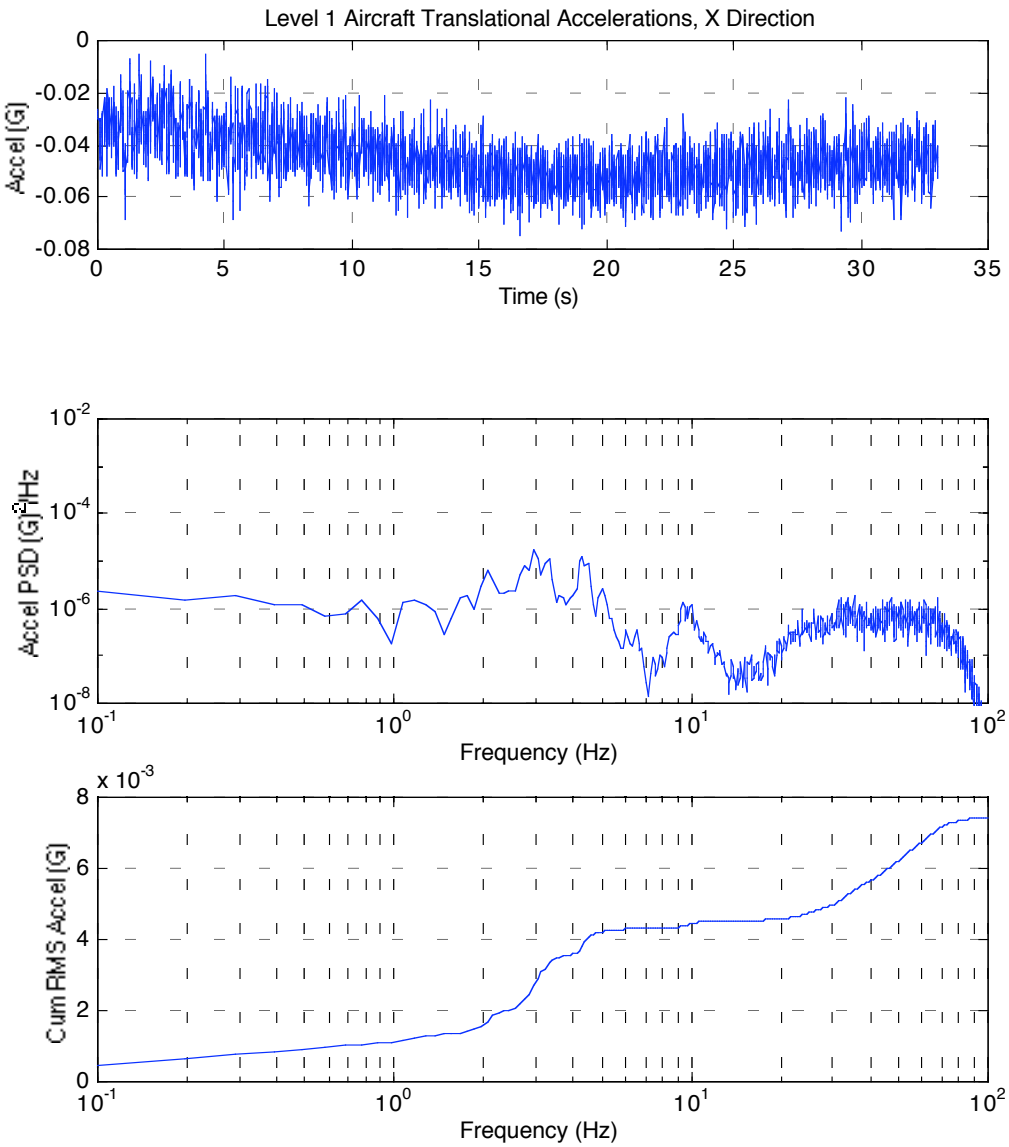


Figure 2C - Level 1 Y-Direction Translational Accelerations

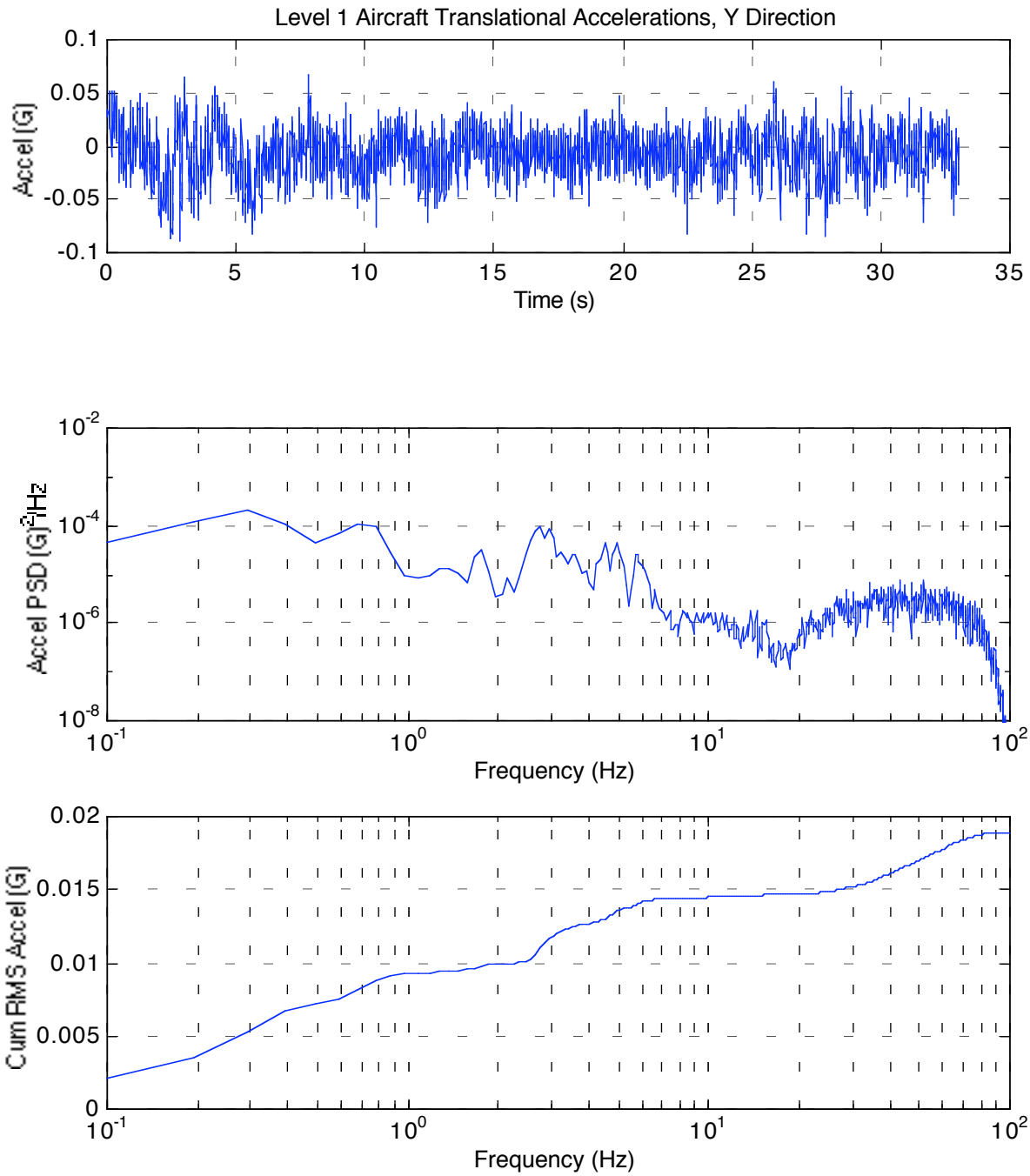


Figure 2D - Level 1 Z-Direction Translational Accelerations

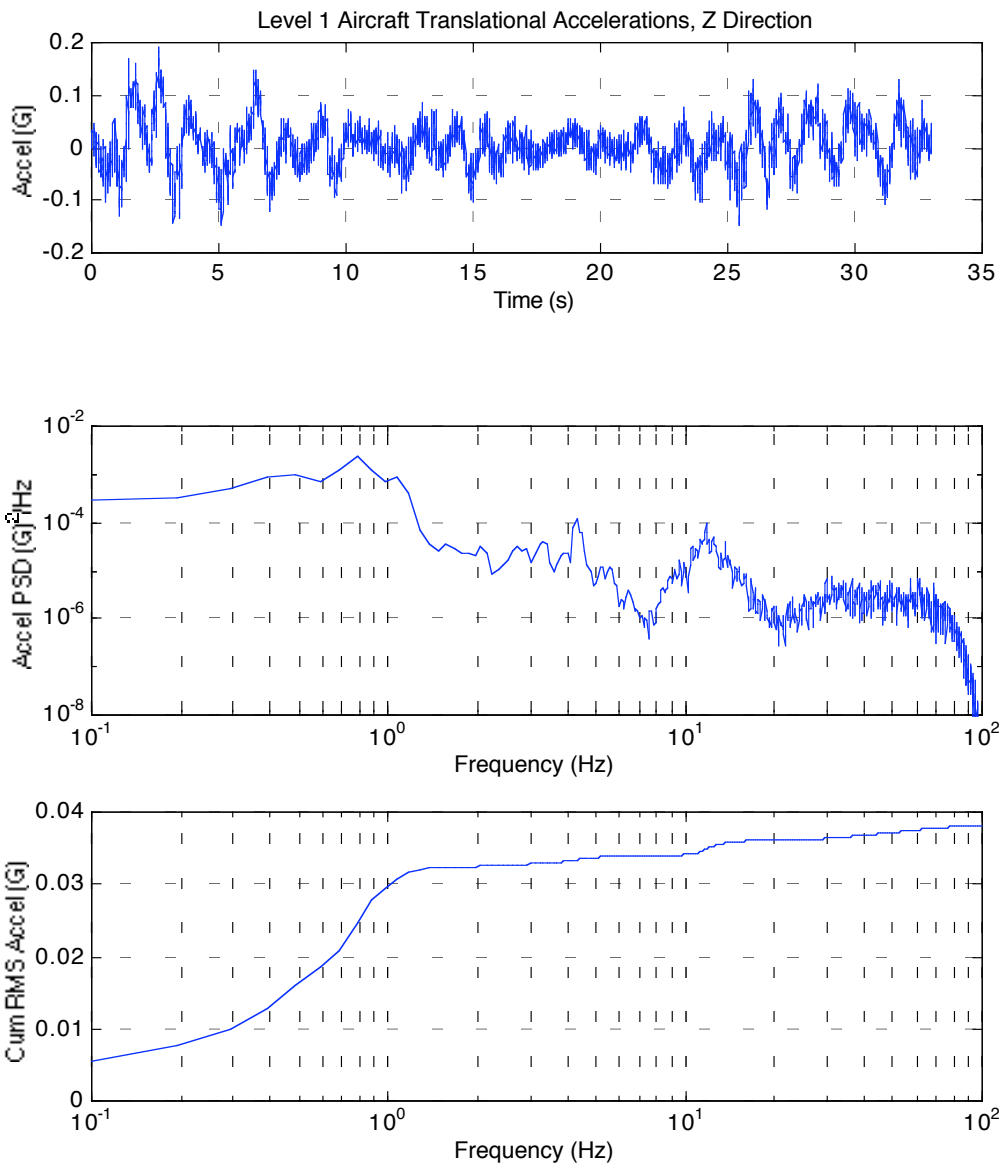


Figure 2E - Level 3 X-Direction Translational Acceleration

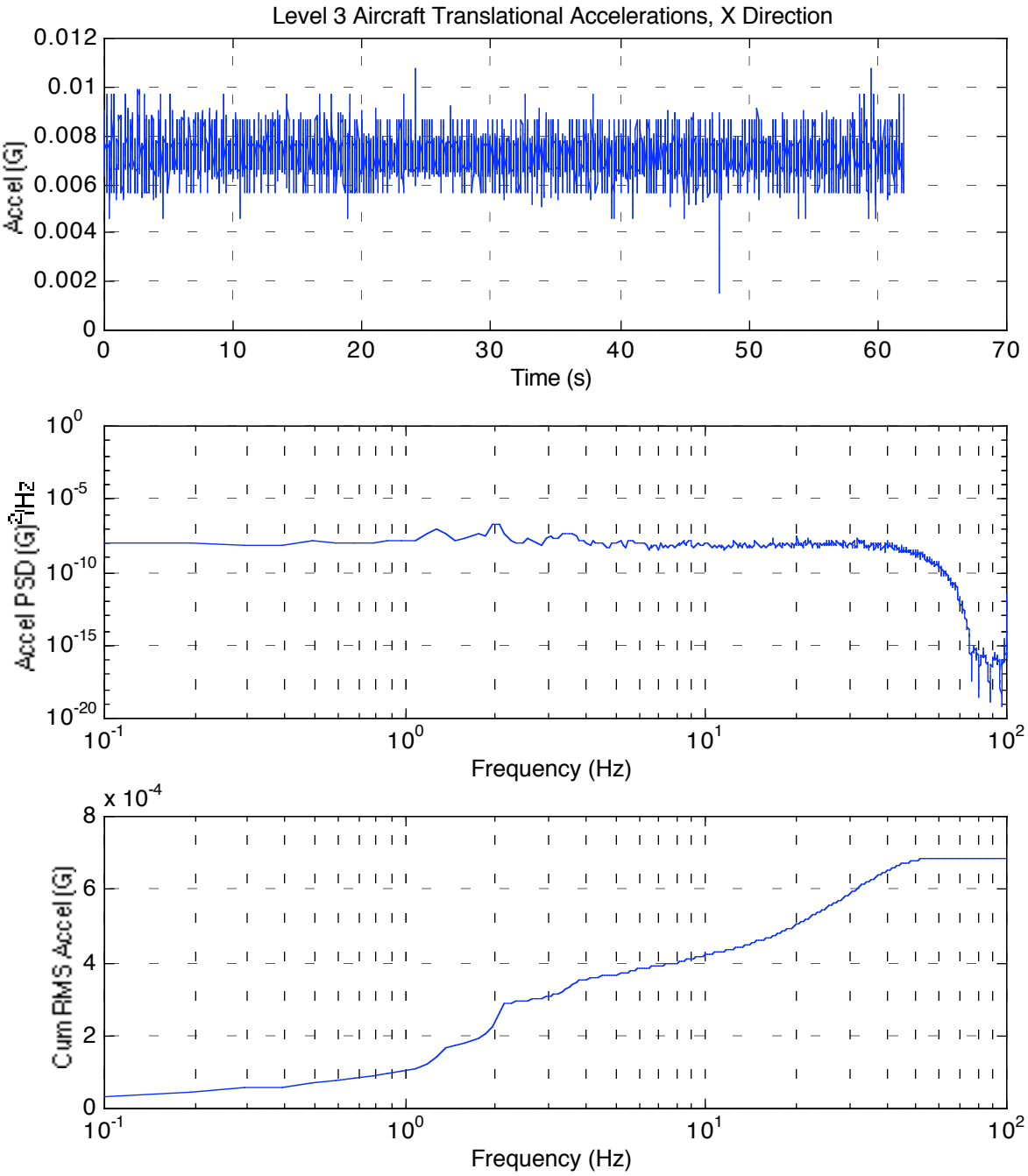


Figure 2F - Level 3 Y-Direction Translational Acceleration

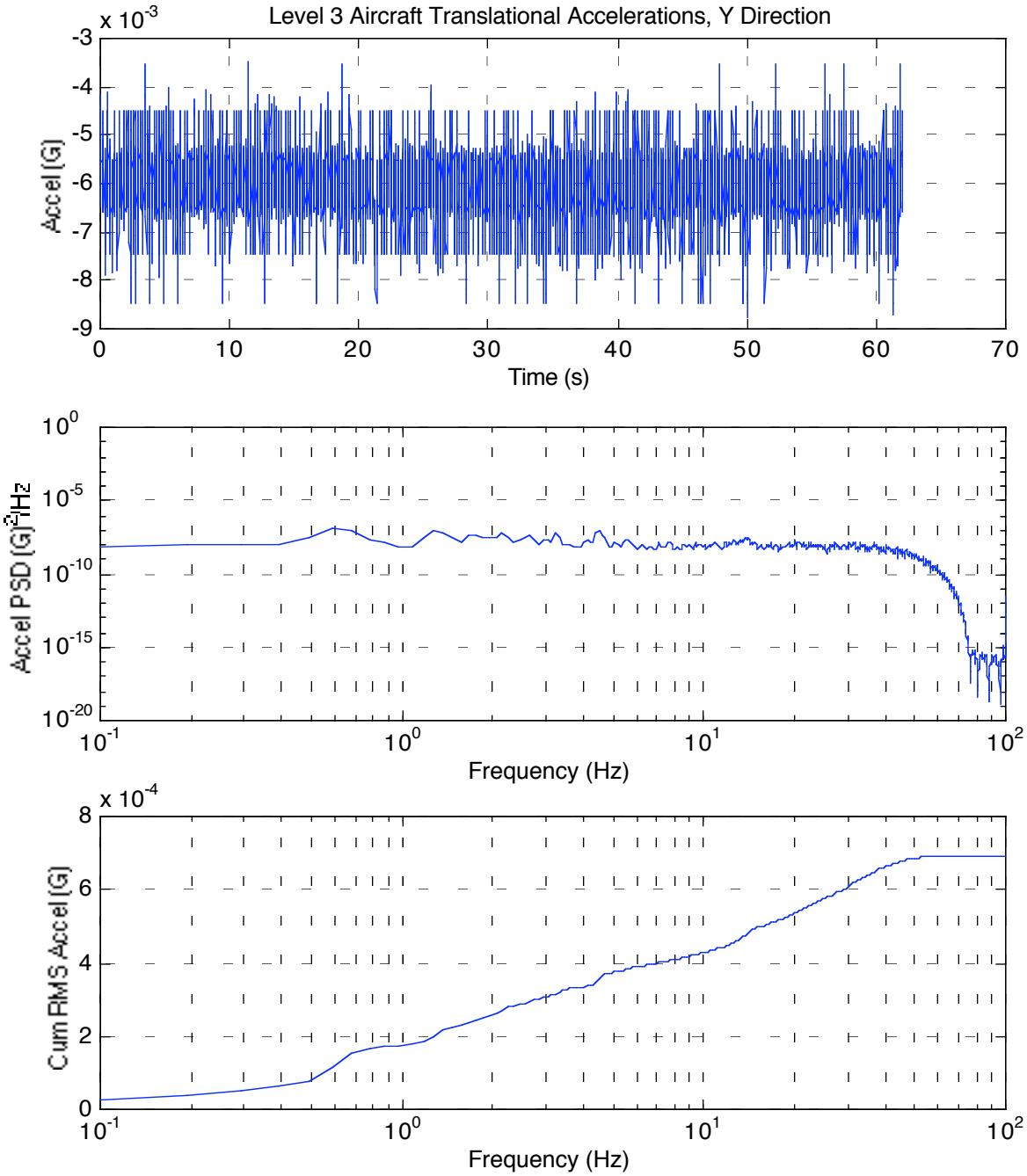
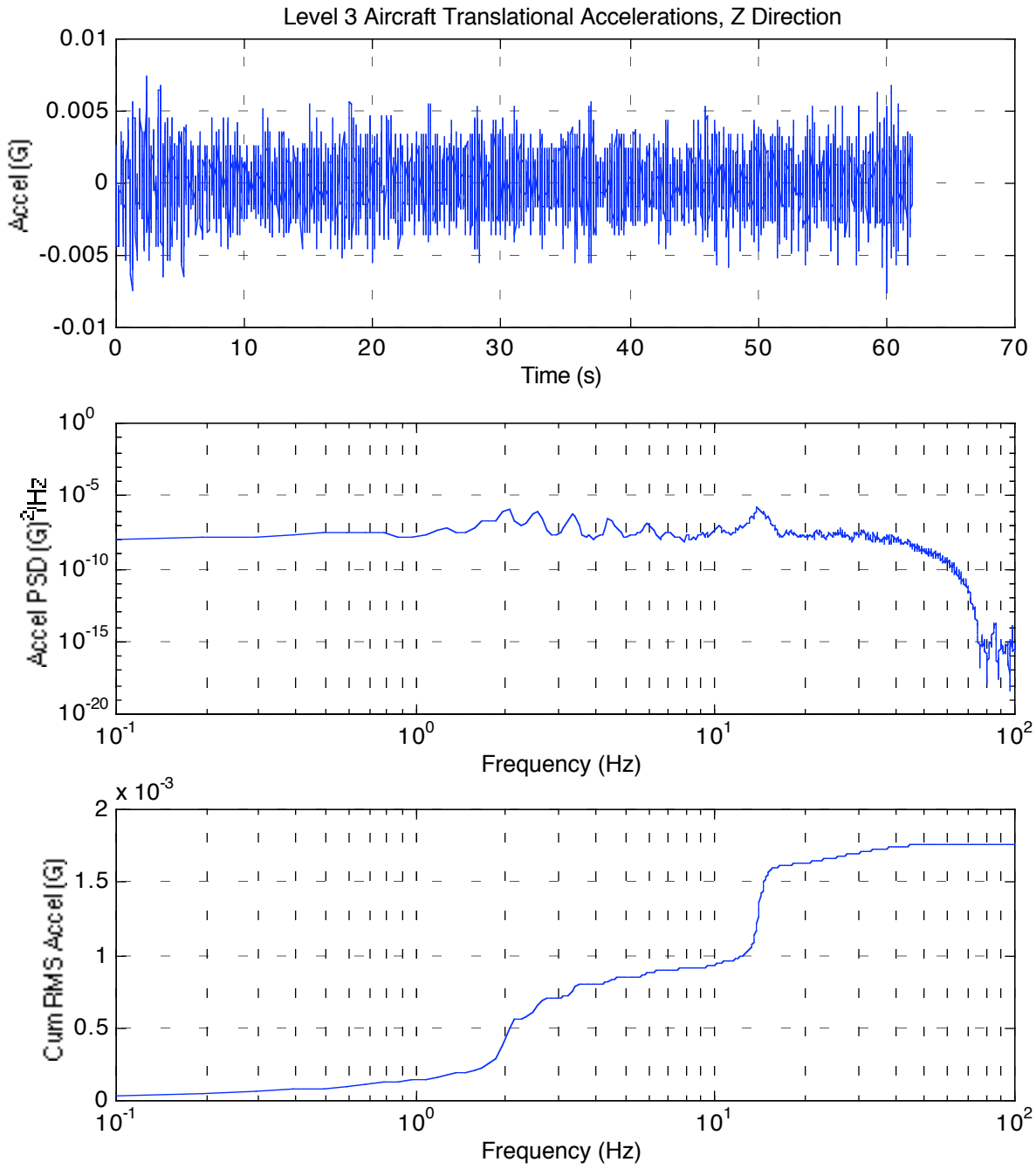


Figure 2G - Level 3 Z-Direction Translational Acceleration



9.2.2 Rotational Motions for TA Performance Evaluation

Figure 2H gives the maximum angular excursions, angular rates, and angular accelerations induced by the aircraft during telescope operating levels 1 and 2 conditions.

Time histories for these dynamic loads are shown in Figures 2I through 2N. Figures 2I, J, & K are charts of aircraft rotational position time histories and their resulting PSDs with cumulative RMS values, for telescope operating level 1 conditions. The actual electronic file of the time histories is provided separately from this document. The aircraft rotation time histories for telescope operating level 2 conditions can be taken as twice the values that are provided in level 1 time histories. Figures 2L, M, & N are charts of aircraft rotational position time histories, and their resulting PSDs with cumulative RMS values, for telescope operating level 3 conditions. The electronic files are named rotLevel1.txt and rotLevel3.txt.

Figure 2I – Aircraft Roll Rotation – Telescope Operating Level 1

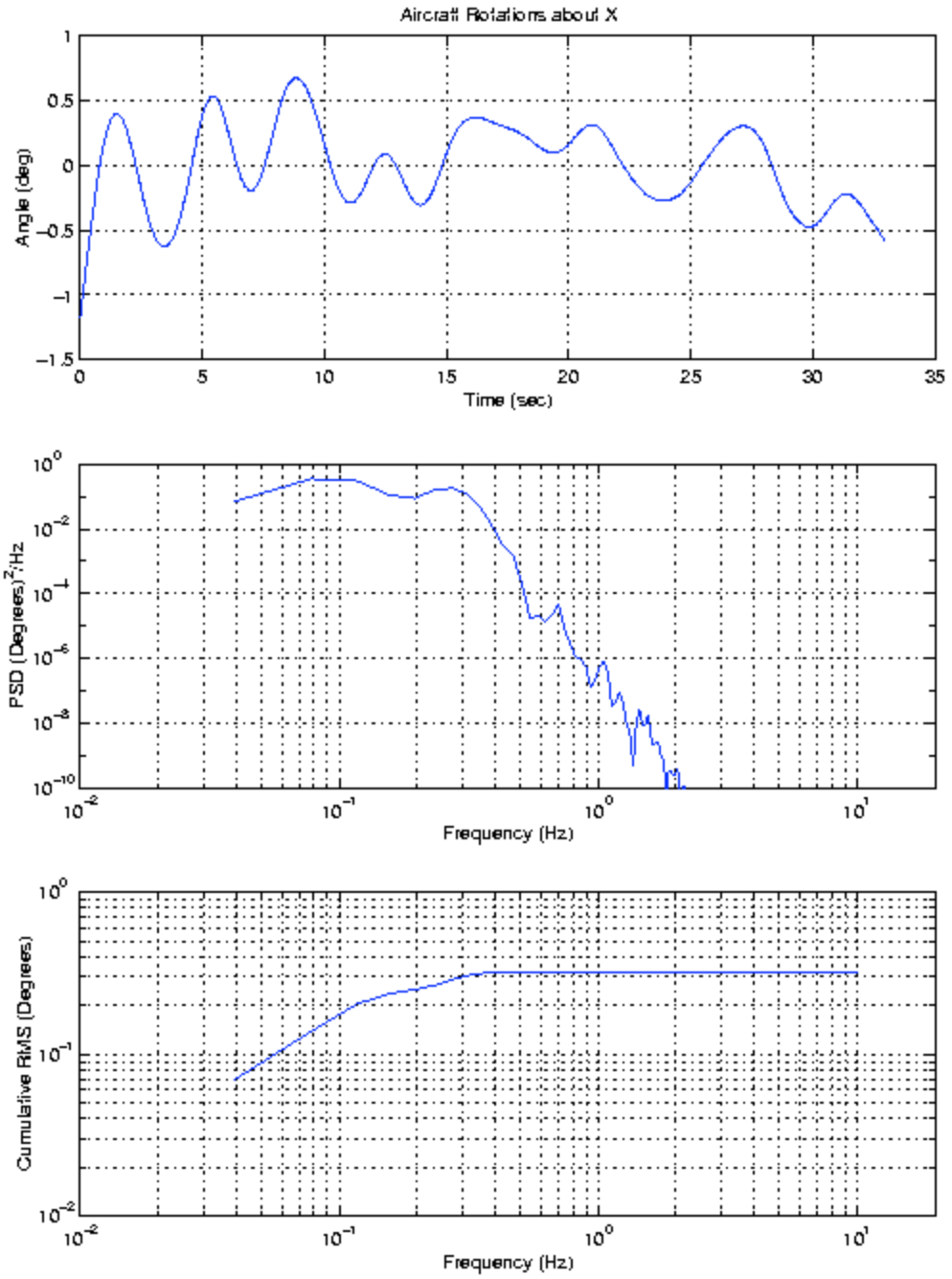


Figure 2J – Aircraft Pitch Rotation – Telescope Operating Level 1

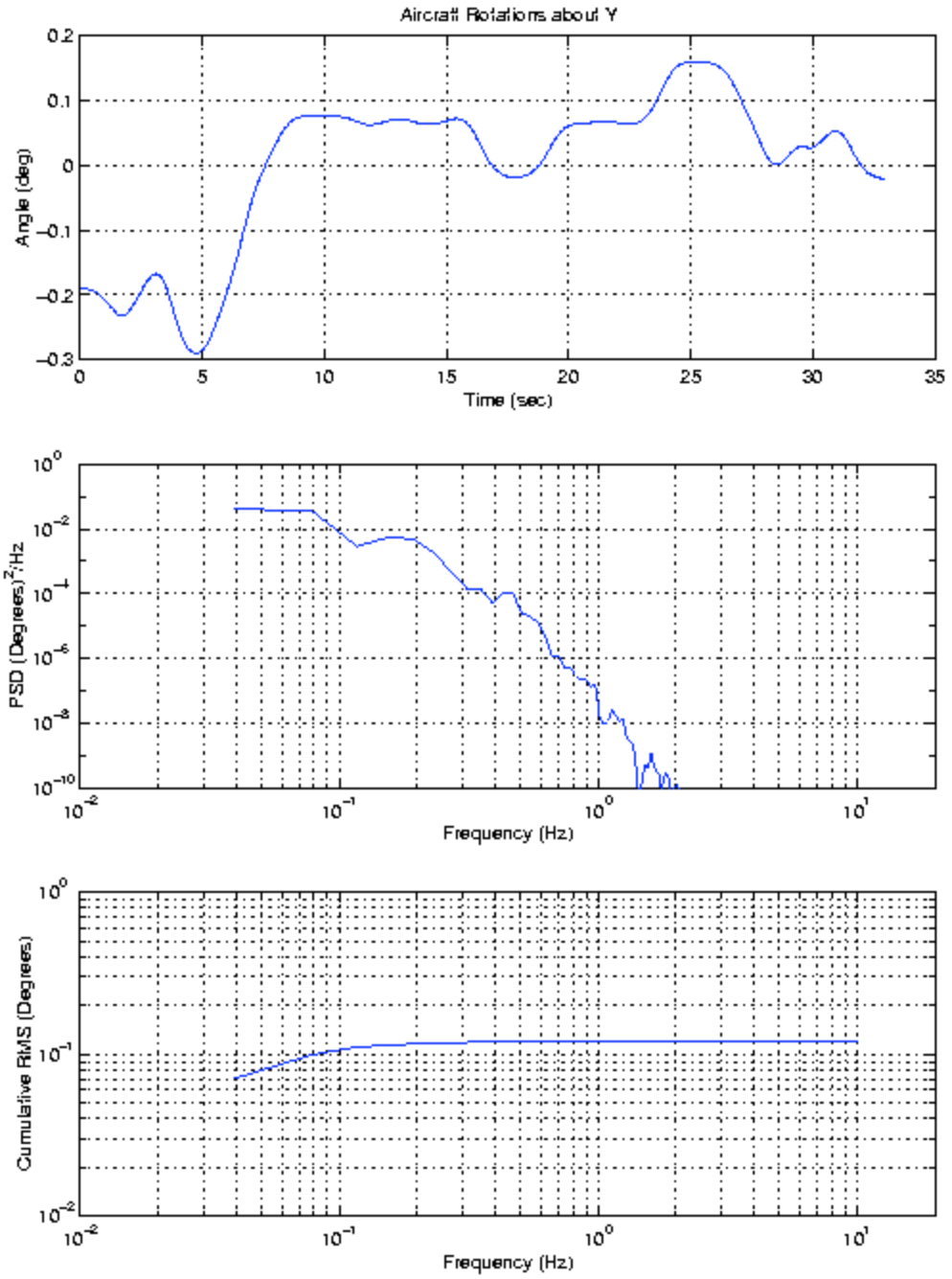


Figure 2K – Aircraft Yaw Rotation – Telescope Operating Level 1

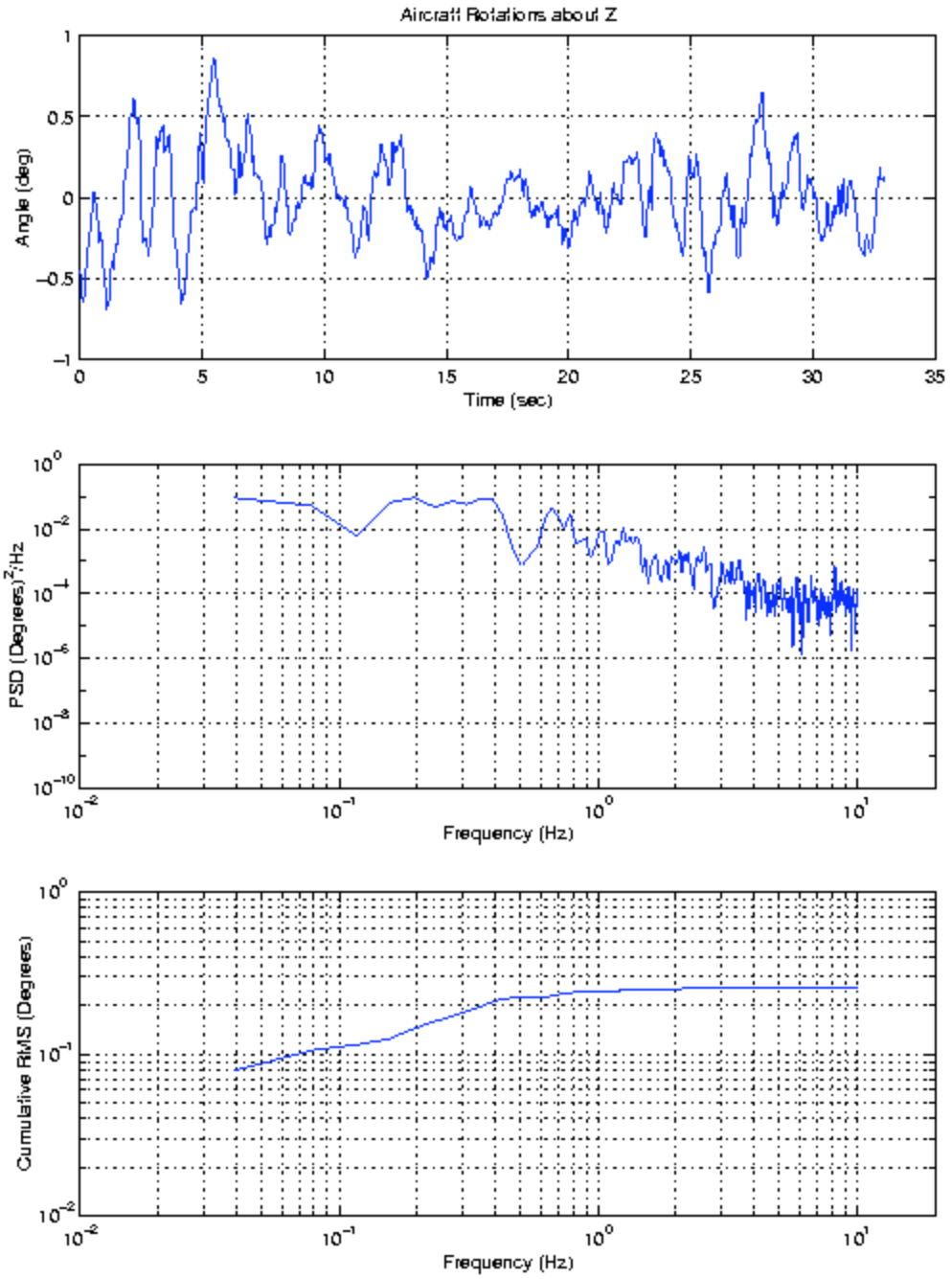


Figure 2L – Aircraft Roll Rotation – Telescope Operating Level 3

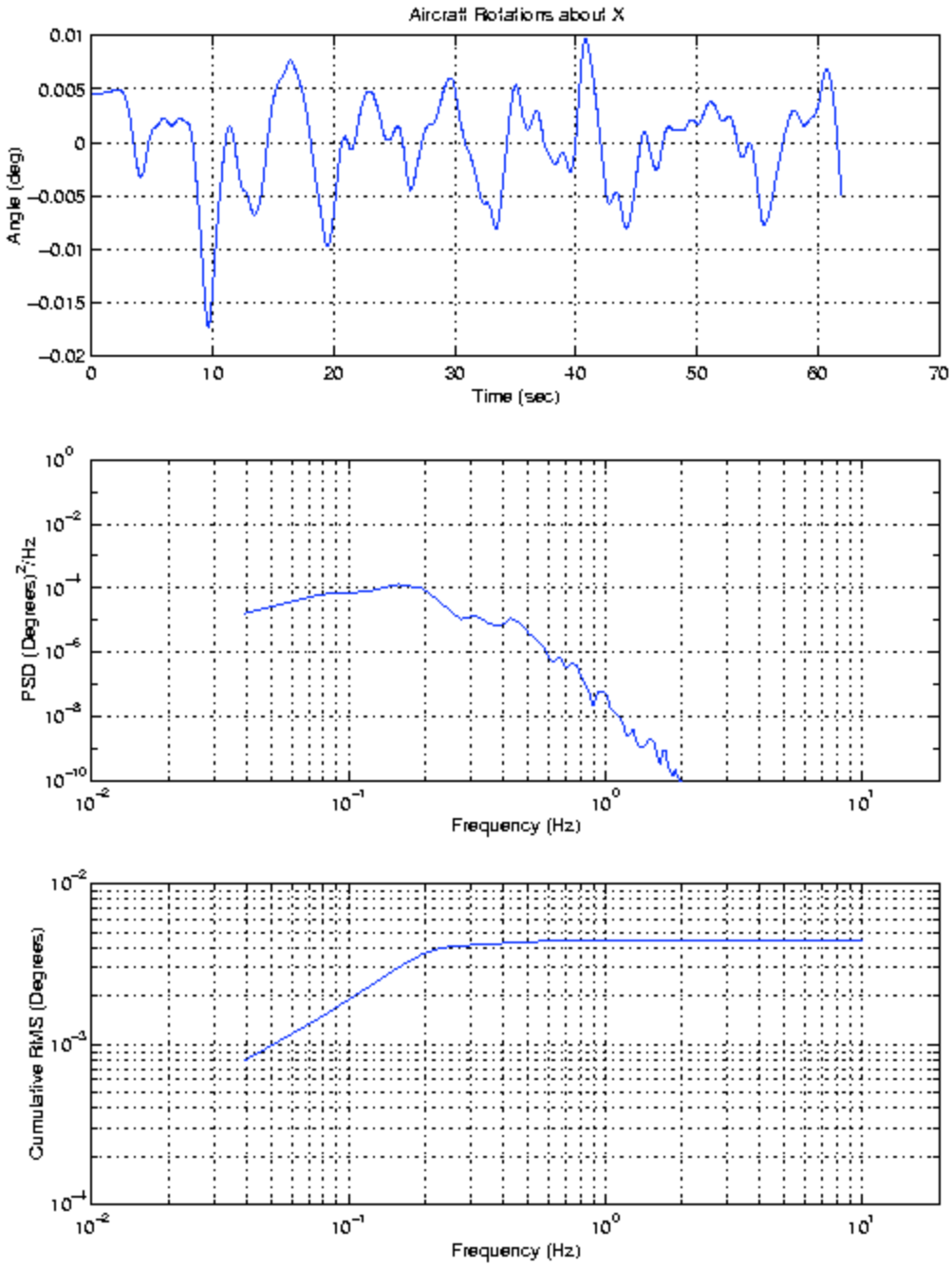


Figure 2M – Aircraft Pitch Rotation – Telescope Operating Level 3

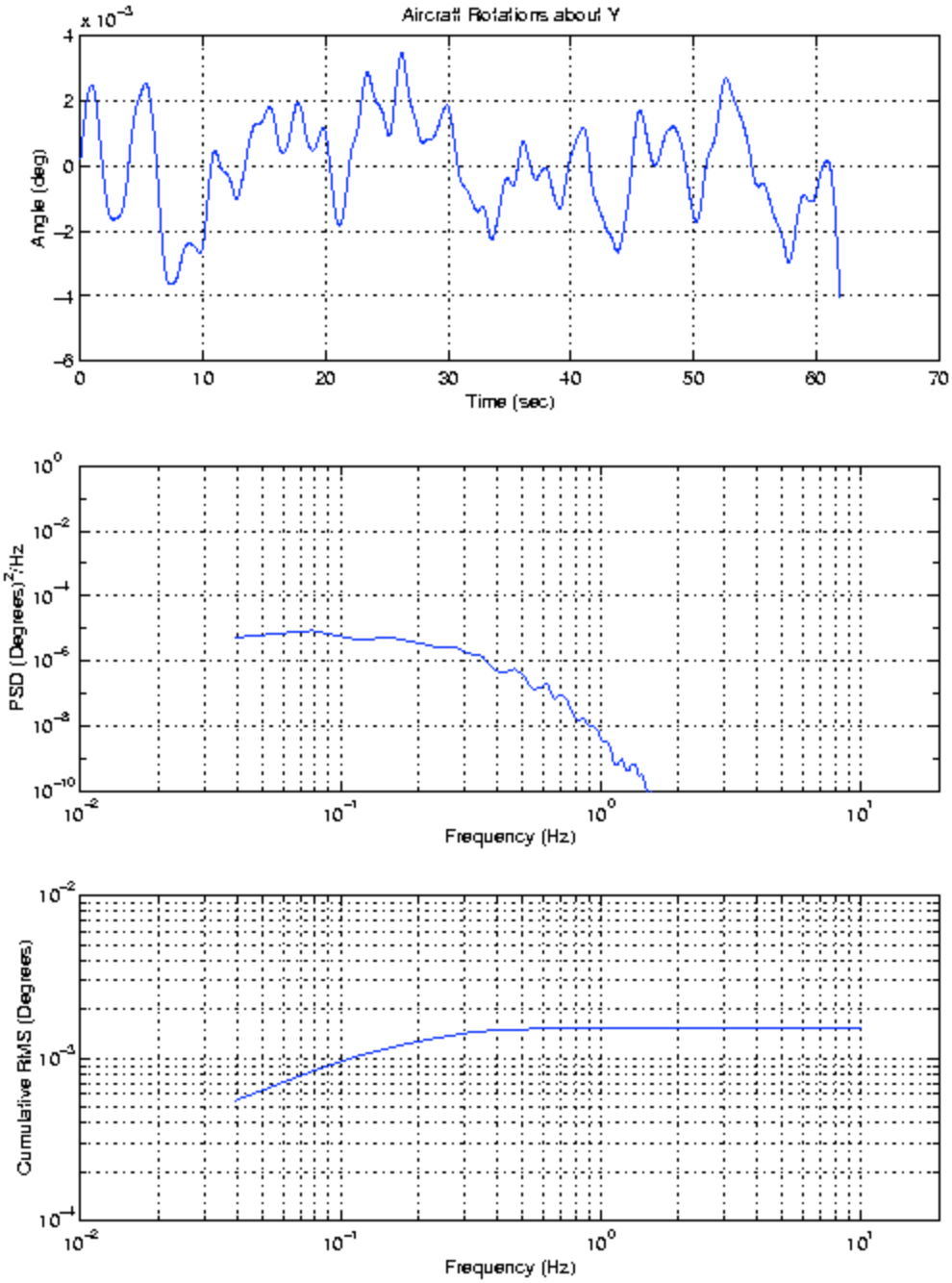
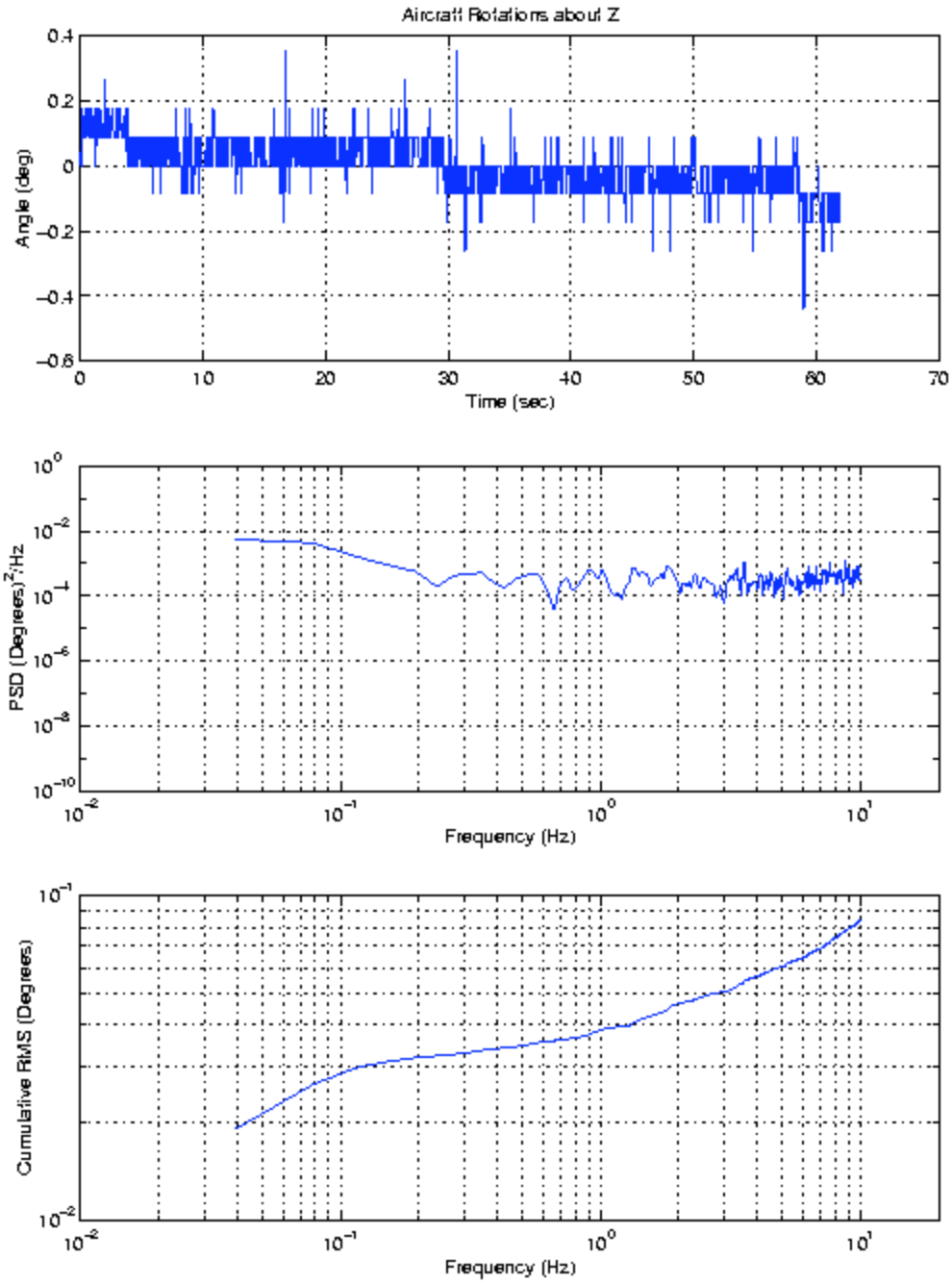


Figure 2N – Aircraft Yaw Rotation – Telescope Operating Level 3



9.2.3 Repeated Loads

For the purpose of TA components' vulnerability to repeated loads, Figures 2O, P, & Q show the load occurrences, or number of times loads occur at a given amplitude, for 40,000 hours of flight and for the vertical, lateral, and axial directions respectively.

For Figures 2O and 2P (Nz and Ny occurrences), the values given for the Ns are actually bands of load factors 0.1 g wide and centered on the N value given. Assume that for N values higher or lower than shown in the figures, occurrences are less than one.

For Figure 2Q (Nx occurrences), load occurrence bands are not specifically considered. The four points given represent discreet occurrences of landing, braking, and take-off thrust in the life of SOFIA.

Nz occurrences in Figure 2O have been divided into four segments of the flight operations: taxi, landing, gust responses, and maneuver responses. Gust and maneuver responses have been further broken into those that occur below 30,000 feet altitude and those that occur above 30,000 feet altitude.

9.2.3.1 Nz Occurrence Time History Profile

Figure 2R presents a time history of vertical acceleration at the telescope assembly bulkhead for analysis of the repeated loads in Figure 20. It shows two occurrences of equal load amplitude but opposite sign. This time history profile represents the most abrupt onset and reversal of vertical acceleration expected at the telescope assembly bulkhead. The magnitude of the profile is normalized to a $\pm$1.0 g change in acceleration from the steady state mean value of 1.0g at cruise.

This time history profile was developed in the following manner. In order to define the worst-case (most abrupt) profile, the critical telescope load conditions from RSC's SOFIA Level 1 analyses (preliminary loads and dynamics analyses) were examined. The critical conditions for vertical acceleration of the telescope were positive and negative vertical gusts encountered during level flight at Vc at an altitude of 20,000 feet. The profile of the gust response was then defined using the gust formula ("1-cosine gust") specified in FAR Part 25.341(b)(1). The magnitude of the response was normalized to 1.0 g, and the period of the response was determined to be 0.80 seconds based on the true airspeed at the above flight condition. An equal gust in the opposite direction was assumed to follow immediately, thereby defining the most abrupt reversal of acceleration at the telescope assembly bulkhead.

For repeated loads analysis, the magnitude of this profile should be scaled by the load level corresponding to the occurrence data under consideration. Note that this time history profile includes one positive excursion as well as one negative excursion.

Figure 2O. Vertical Load Occurrences

Nz Taxi Occurrences/per 6000 Flts	
Nz	Occurrences per 6000 Flights
0.25	0
0.35	1
0.45	24
0.55	540
0.65	12000
0.75	162000
0.85	990000
0.95	1800000
1.05	1800000
1.15	990000
1.25	162000
1.35	12000
1.45	540
1.55	24
1.65	1
1.75	0
Sum	5929130

Nz Landing Occurrences /6000 Flts	
Positive Nz	Occurrences Per 6000 flights
1.11	1726
1.23	2781
1.34	2494
1.45	1487
1.57	748
1.68	249
1.79	77
1.91	14
2.02	10
2.13	5
Sum	9591

Nz Gust Occurrences per 40000 Hours		
Nz	Below 30 K	Above 30 K
-0.75	1	0
-0.65	1	0
-0.55	1	0
-0.45	2	0
-0.35	4	1
-0.25	7	1
-0.15	17	2
-0.05	30	3
0.05	61	6
0.15	184	11
0.25	391	26
0.35	1063	79
0.45	2437	321
0.55	9765	1635
0.65	26035	13915
0.75	104604	107628
0.85	255396	676372
0.95	1133540	3550347
1.05	1133540	3550347
1.15	255396	676372
1.25	104604	107628
1.35	26035	13915
1.45	9765	1635
1.55	2437	321
1.65	1063	79
1.75	391	26
1.85	184	11
1.95	61	6
2.05	30	3
2.15	17	2
2.25	7	1
2.35	4	1
2.45	2	0
2.55	1	0
2.65	1	0
2.75	1	0
Sum	3067079	8700694

Nz Maneuver Occurrences Per 40000 Hours		
	Below	Above
Nz	30 K	30 K
-0.05	0	3
0.05	0	9
0.15	1	36
0.25	5	145
0.35	23	575
0.45	104	2285
0.55	476	9079
0.65	2187	36082
0.75	10050	143399
0.85	46184	569900
0.95	212282	2264922
1.05	212282	2264922
1.15	46184	569900
1.25	10050	143399
1.35	2187	36082
1.45	476	9079
1.55	104	2285
1.65	23	575
1.75	5	145
1.85	1	36
1.95	0	9
2.05	0	3
Sum	542623	6052871

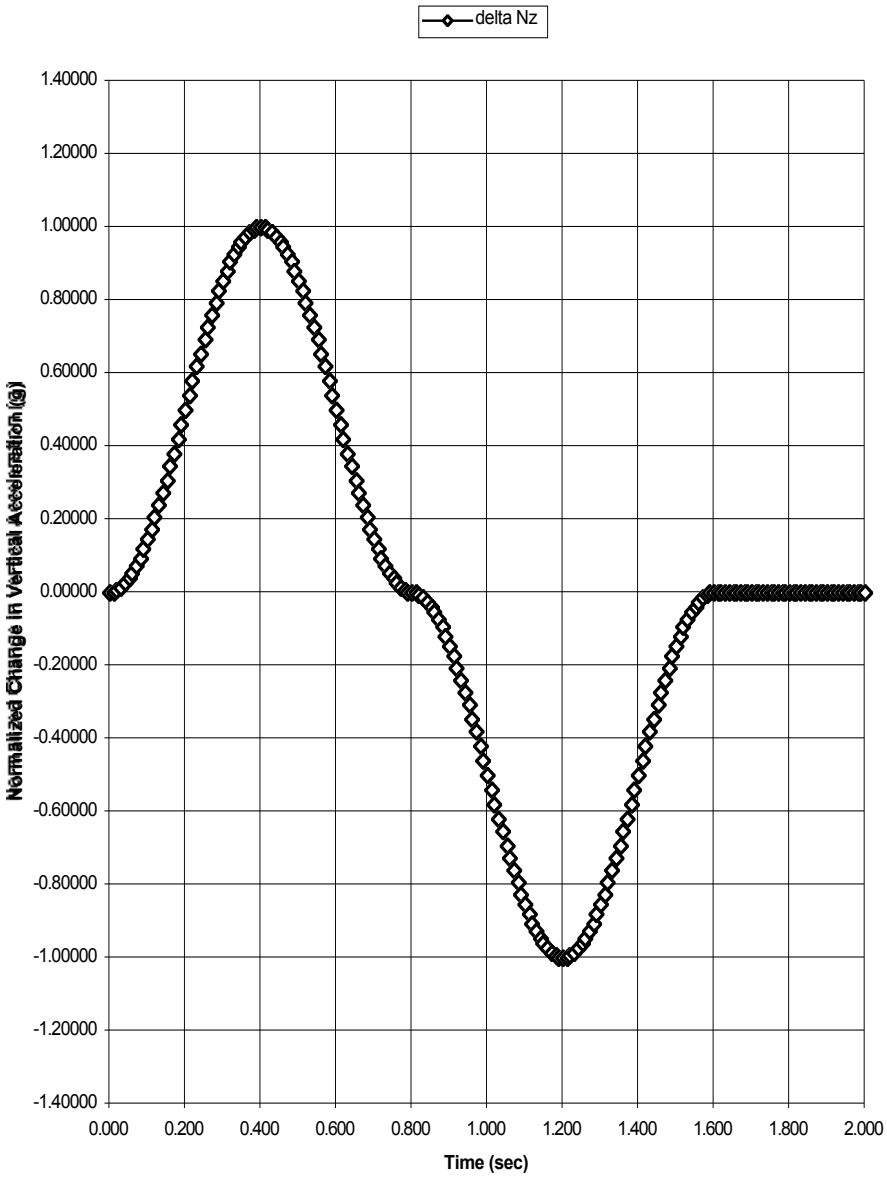
Figure 2P. Lateral Load Occurrences

Ny	OCCURRENCES
-1	2
-0.9	1
-0.8	52
-0.7	73
-0.6	268
-0.5	1436
-0.4	14048
-0.3	46079
-0.2	210614
-0.1	1169820
0.1	1169820
0.2	210614
0.3	46079
0.4	14048
0.5	1382
0.6	312
0.7	81
0.8	55
0.9	1
1	2

Figure 2Q. Axial Load Occurrences

Nx	OCCURRENCES
0.575	124000
0.287	310000
0.25	62000
-0.25	6000

Figure 2R Normalized Time History Profile for Repeated Loads
Worst-Case Vertical Acceleration at the Telescope Assembly Bulkhead



Normalized Time History Profile for Repeated Loads Worst-Case Vertical Acceleration at the Telescope Assembly Bulkhead

For 0 ≤ t ≤ 0.800,
dNz = 0.5*(1-cos(2*pi*t/0.8))

t (sec)	delta Nz (g)	t (sec)	delta Nz (g)
0.000	0.00000		
0.010	0.00154	0.410	0.99846
0.020	0.00616	0.420	0.99384
0.030	0.01382	0.430	0.98618
0.040	0.02447	0.440	0.97553
0.050	0.03806	0.450	0.96194
0.060	0.05450	0.460	0.94550
0.070	0.07368	0.470	0.92632
0.080	0.09549	0.480	0.90451
0.090	0.11980	0.490	0.88020
0.100	0.14645	0.500	0.85355
0.110	0.17528	0.510	0.82472
0.120	0.20611	0.520	0.79389
0.130	0.23875	0.530	0.76125
0.140	0.27300	0.540	0.72700
0.150	0.30866	0.550	0.69134
0.160	0.34549	0.560	0.65451
0.170	0.38328	0.570	0.61672
0.180	0.42178	0.580	0.57822
0.190	0.46077	0.590	0.53923
0.200	0.50000	0.600	0.50000
0.210	0.53923	0.610	0.46077
0.220	0.57822	0.620	0.42178
0.230	0.61672	0.630	0.38328
0.240	0.65451	0.640	0.34549
0.250	0.69134	0.650	0.30866
0.260	0.72700	0.660	0.27300
0.270	0.76125	0.670	0.23875
0.280	0.79389	0.680	0.20611
0.290	0.82472	0.690	0.17528
0.300	0.85355	0.700	0.14645
0.310	0.88020	0.710	0.11980
0.320	0.90451	0.720	0.09549
0.330	0.92632	0.730	0.07368
0.340	0.94550	0.740	0.05450
0.350	0.96194	0.750	0.03806
0.360	0.97553	0.760	0.02447
0.370	0.98618	0.770	0.01382
0.380	0.99384	0.780	0.00616
0.390	0.99846	0.790	0.00154
0.400	1.00000	0.800	0.00000

For 0.800 < t ≤ 1.600,
dNz = -0.5*(1-cos(2*pi*t/0.8))

t (sec)	delta Nz (g)	t (sec)	delta Nz (g)
0.810	-0.00154	1.210	-0.99846
0.820	-0.00616	1.220	-0.99384
0.830	-0.01382	1.230	-0.98618
0.840	-0.02447	1.240	-0.97553
0.850	-0.03806	1.250	-0.96194
0.860	-0.05450	1.260	-0.94550
0.870	-0.07368	1.270	-0.92632
0.880	-0.09549	1.280	-0.90451
0.890	-0.11980	1.290	-0.88020
0.900	-0.14645	1.300	-0.85355
0.910	-0.17528	1.310	-0.82472
0.920	-0.20611	1.320	-0.79389
0.930	-0.23875	1.330	-0.76125
0.940	-0.27300	1.340	-0.72700
0.950	-0.30866	1.350	-0.69134
0.960	-0.34549	1.360	-0.65451
0.970	-0.38328	1.370	-0.61672
0.980	-0.42178	1.380	-0.57822
0.990	-0.46077	1.390	-0.53923
1.000	-0.50000	1.400	-0.50000
1.010	-0.53923	1.410	-0.46077
1.020	-0.57822	1.420	-0.42178
1.030	-0.61672	1.430	-0.38328
1.040	-0.65451	1.440	-0.34549
1.050	-0.69134	1.450	-0.30866
1.060	-0.72700	1.460	-0.27300
1.070	-0.76125	1.470	-0.23875
1.080	-0.79389	1.480	-0.20611
1.090	-0.82472	1.490	-0.17528
1.100	-0.85355	1.500	-0.14645
1.110	-0.88020	1.510	-0.11980
1.120	-0.90451	1.520	-0.09549
1.130	-0.92632	1.530	-0.07368
1.140	-0.94550	1.540	-0.05450
1.150	-0.96194	1.550	-0.03806
1.160	-0.97553	1.560	-0.02447
1.170	-0.98618	1.570	-0.01382
1.180	-0.99384	1.580	-0.00616
1.190	-0.99846	1.590	-0.00154
1.200	-1.00000	1.600	0.00000

Note: For t>1.600, dNz = 0

9.2.4 Factors of Safety

Limit load cases shall be applied to the TA system when it is both caged and uncaged, braked and unbraked, and operating in any of its required operating modes, and there shall be no resulting damage which degrades subsequent performance of any TA system or subsystem.

In order to insure that TA performance degradation does not occur after exposure to limit loads, the following minimum design safety factors shall be used for the TA subsystems:

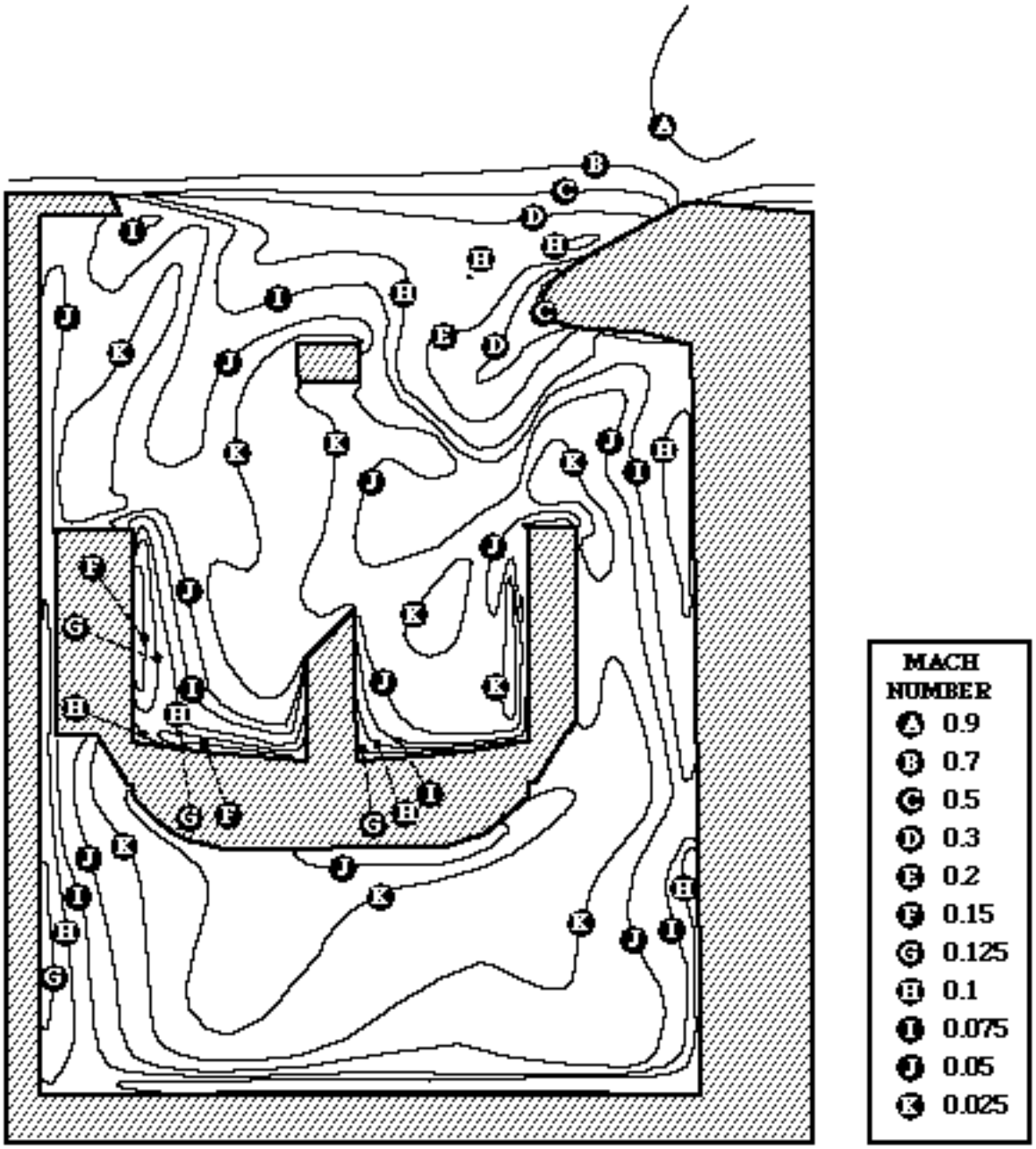
Design and Test Options	Minimum Design Factor of Safety on Limit Loads Yield (FSy)
1. With test	1.10
2. Without test	1.40

9.3 (Deleted)

9.4 WIND

During telescope operation the cavity will experience a steady-state wind. Figure 4 depicts this environment. The Mach number contours depicted in this figure are for a plane down the center of the aperture. Note that the Mach number levels given here are dependent upon a specific cavity and telescope geometry.

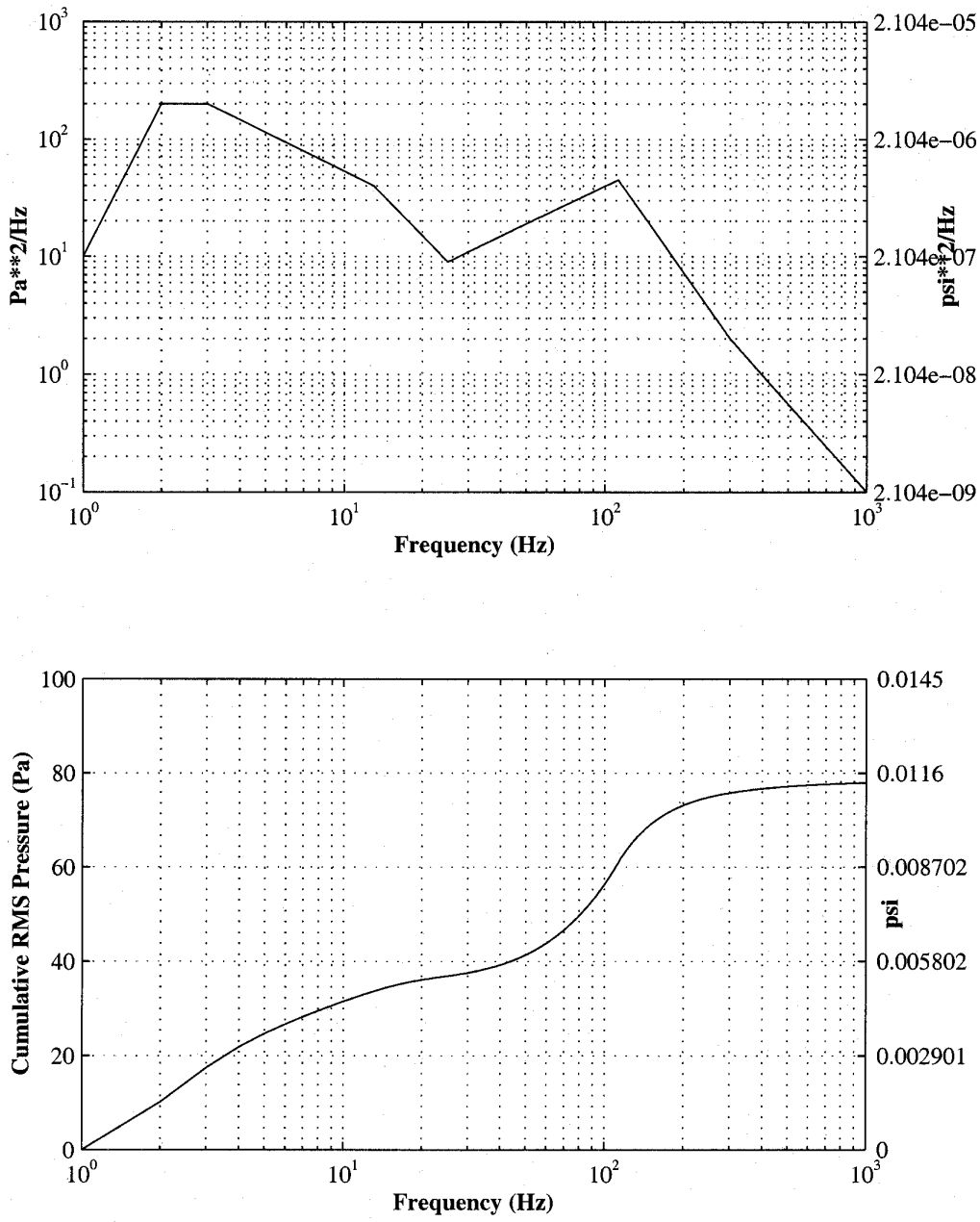
Figure 4. Cavity Wind Environment – Mach Number Contours



9.5 CAVITY PRESSURE FLUCTUATION ENVIRONMENT

During telescope operation the air within the cavity will experience pressure fluctuations. The maximum acoustic PSD is given in Figure 5. The telescope must meet performance specifications when subjected to this environment.

Figure 5. Cavity Pressure Fluctuation Environment



9.6 TORQUES IMPARTED TO TELESCOPE ASSEMBLY

During telescope operation, pressure fluctuations and wind loading within the cavity will cause dynamic and steady torques to be applied to the Telescope Assembly. The maximum dynamic torque PSD is given in Figure 6A, 6B, and 6C. The loads imparted to the telescope are determined in part by the particular design of the telescope, so the loads specified herein may not be valid if the telescope configuration changes substantially from that which is depicted in Figure 6E. Figure 6A gives the moment PSD about the telescope elevation axis, Figure 6B gives the moment PSD about cross-elevation, and Figure 6C gives the moment PSD about line-of-sight. The top graph in each figure gives the PSD of the moments and the bottom graph gives the cumulative RMS value of the moments at each frequency.

The aero-acoustic torques are applied as a pressure distribution on the entire telescope surface that is exposed to the cavity environment. For the purpose of generating an analytic model to verify performance, the dynamic moments should be applied as a set of time varying pressures on designated telescope areas as defined by the TA pressure area views in Figure 6E and the geometric tabulations in Figure 6F. Alternately, the resulting forces from pressures applied over the designated areas, may be applied. The actual pressure and force data is provided in computer files and made available in two alternative file formats: ASCII text files and Matlab .mat binary data files. The files contain pressure and force values at 56 locations on the telescope, occurring at 820-microsecond intervals for a period of 41 seconds (50,000 points in time). Each of the 56 locations represents the centroid of an area. Figure 6F shows the centroid positions (called sensor numbers), their sensor location numbers as shown in Figure 6E, the data row numbers in the computer files, their positions in the TA coordinate system, and their associated areas projected on the TA's principal planes. The file names are wtDataTable.txt, wtForceDataML.mat, wtForceDataText.txt, wtPresDataML.mat, and wtPresDataText.txt. They are located on NASA Ames server jean-luc.arc.nasa.gov in directory /wtdata/sofia5.

The Figure 6E depicts and labels the 56 centroid positions. Some points are labeled with two numbers - the top number represents the point on the top surface shown in the view, the bottom number represents the point on the hidden bottom surface.

The pressure data (labeled wtPresData in the files) are pressure values in units of pounds per square inch. The force data (labeled wtForceData) are force values in units of Newtons.

Applying the pressure loads presented in the computer file and described in Figure 6E and its accompanying table is the equivalent of applying all the moment PSDs shown in Figures 6A, B, and C simultaneously, using the correct time correlation.

The static moments are specified in Figure 6D. These loads should be realized as a pressure distribution on the surfaces of the telescope components which occupy the cavity. Applying the static moments as pure couples about the rotation axes is not a valid interpretation of the environment.

Figure 6A. Unsteady Torque Imparted to Telescope Assembly Due to Pressure Fluctuations - TA Elevation Axis

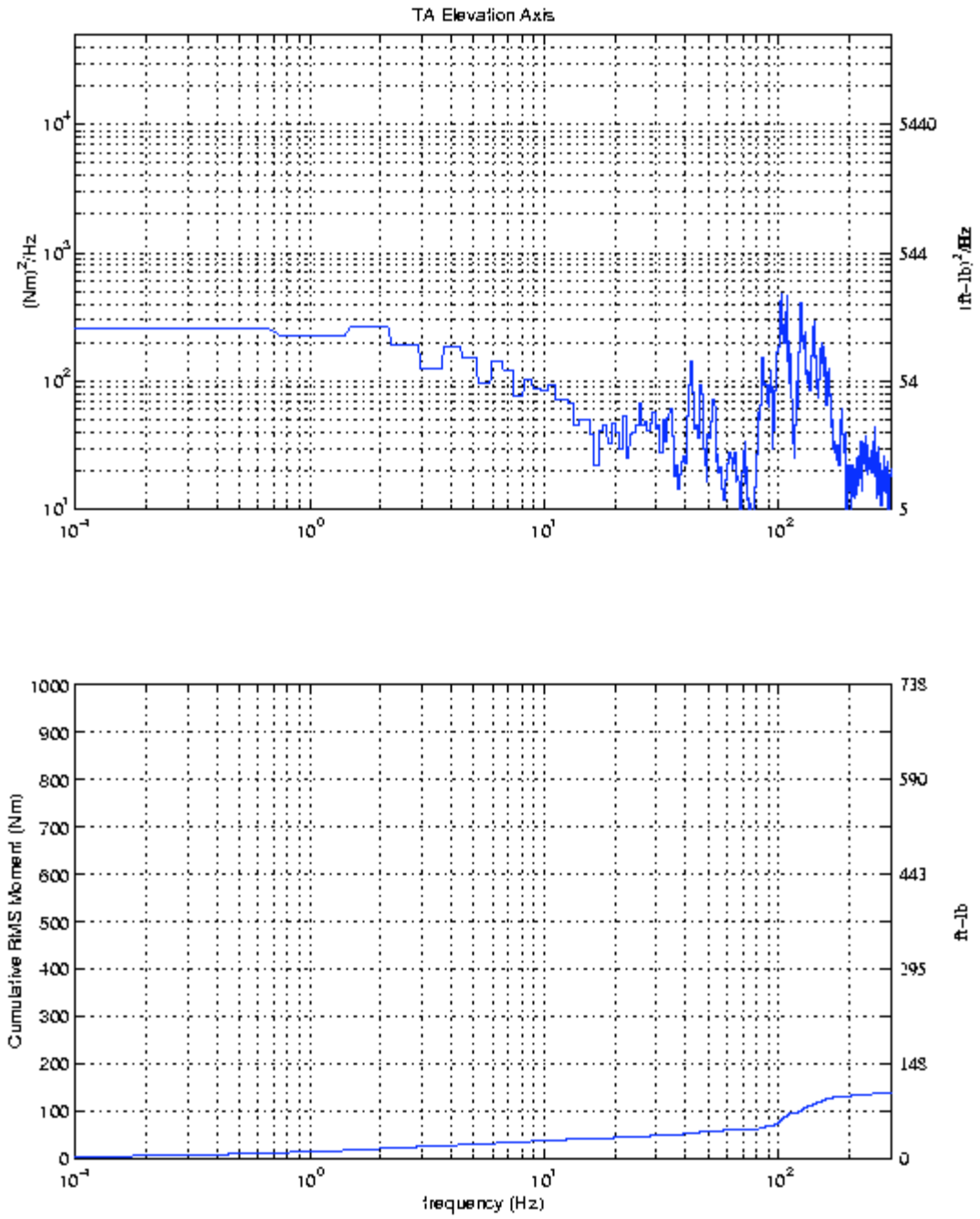


Figure 6B. Unsteady Torque Imparted to Telescope Assembly Due to Pressure Fluctuations - TA Cross-Elevation Axis

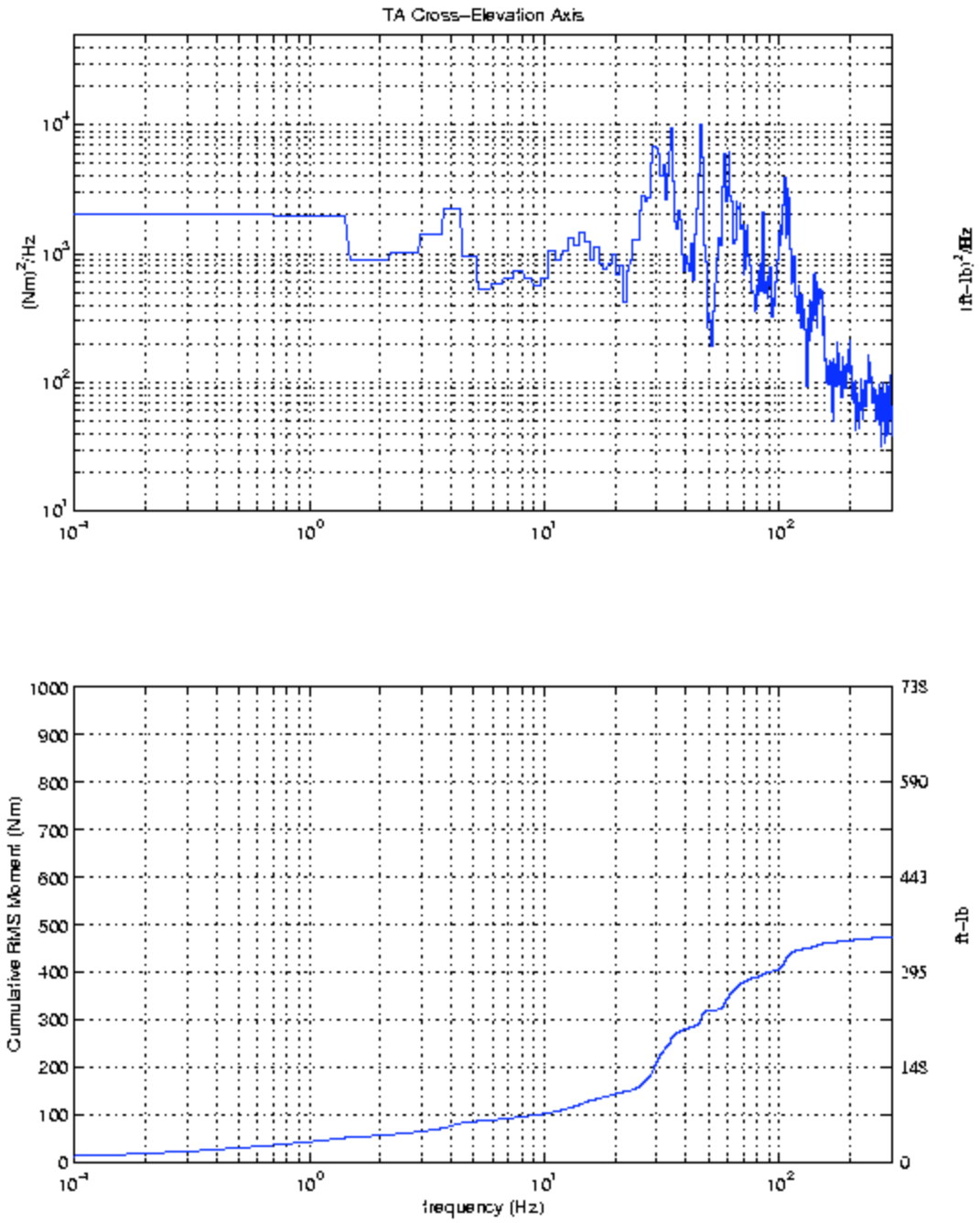


Figure 6C. Unsteady Torque Imparted to Telescope Assembly Due to Pressure Fluctuations - TA LOS Axis

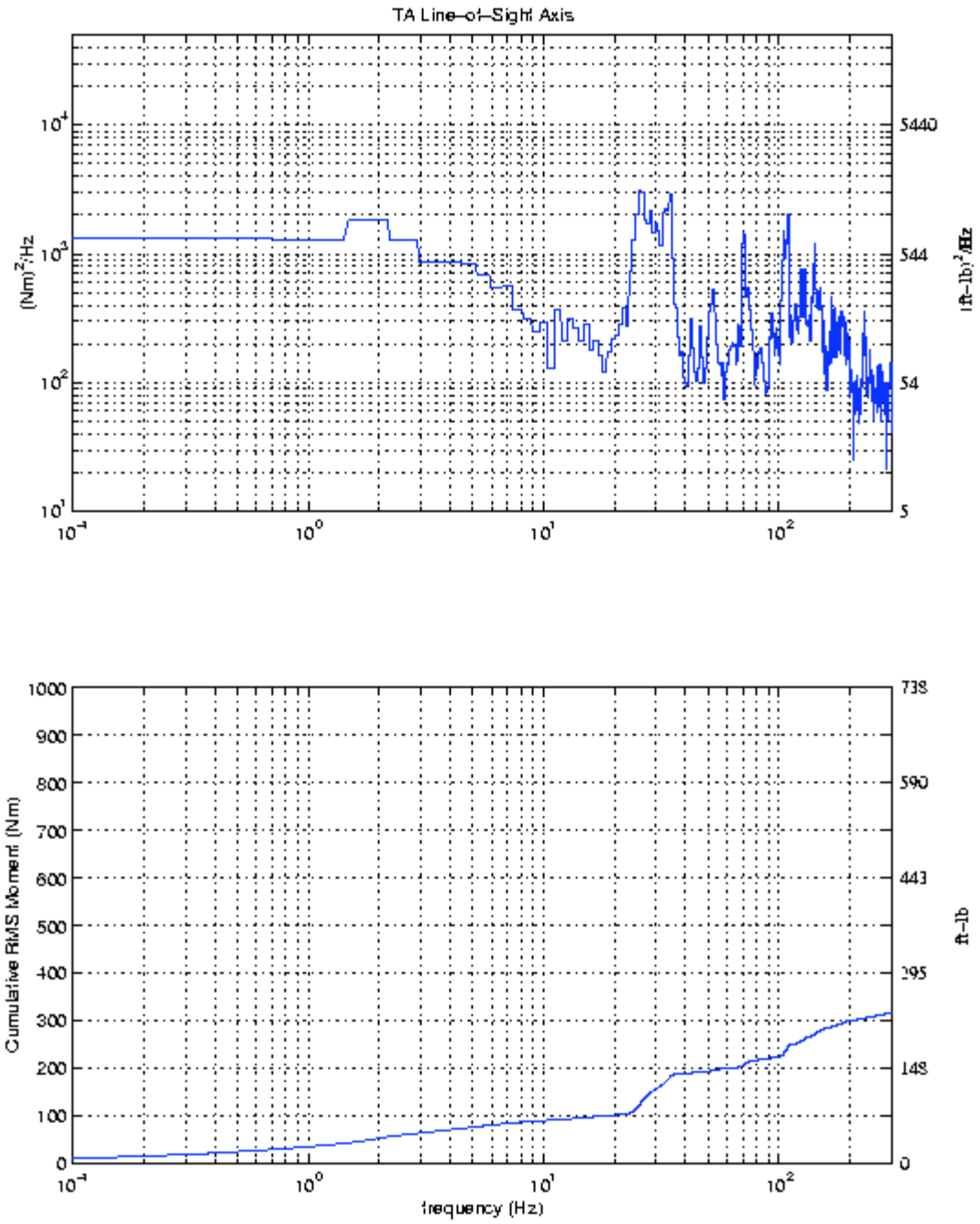


Figure 6D. Static Telescope Moments

	Truss Telescope
Elevation Axis	-278 N-m (-205 ft-lb)
Cross-Elevation Axis	-447 N-m (-330 ft-lb)
Line-of-Sight Axis	400 N-m (295 ft-lb)

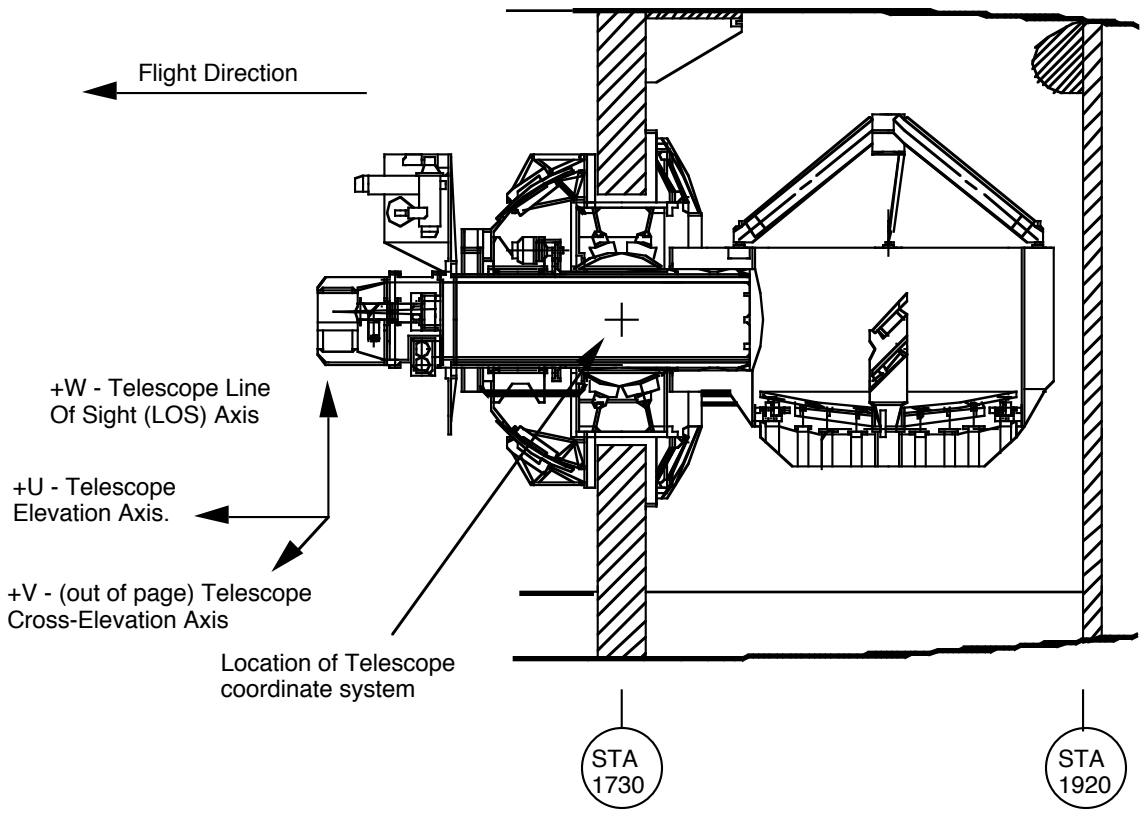


Figure 6E. TA Pressure Areas

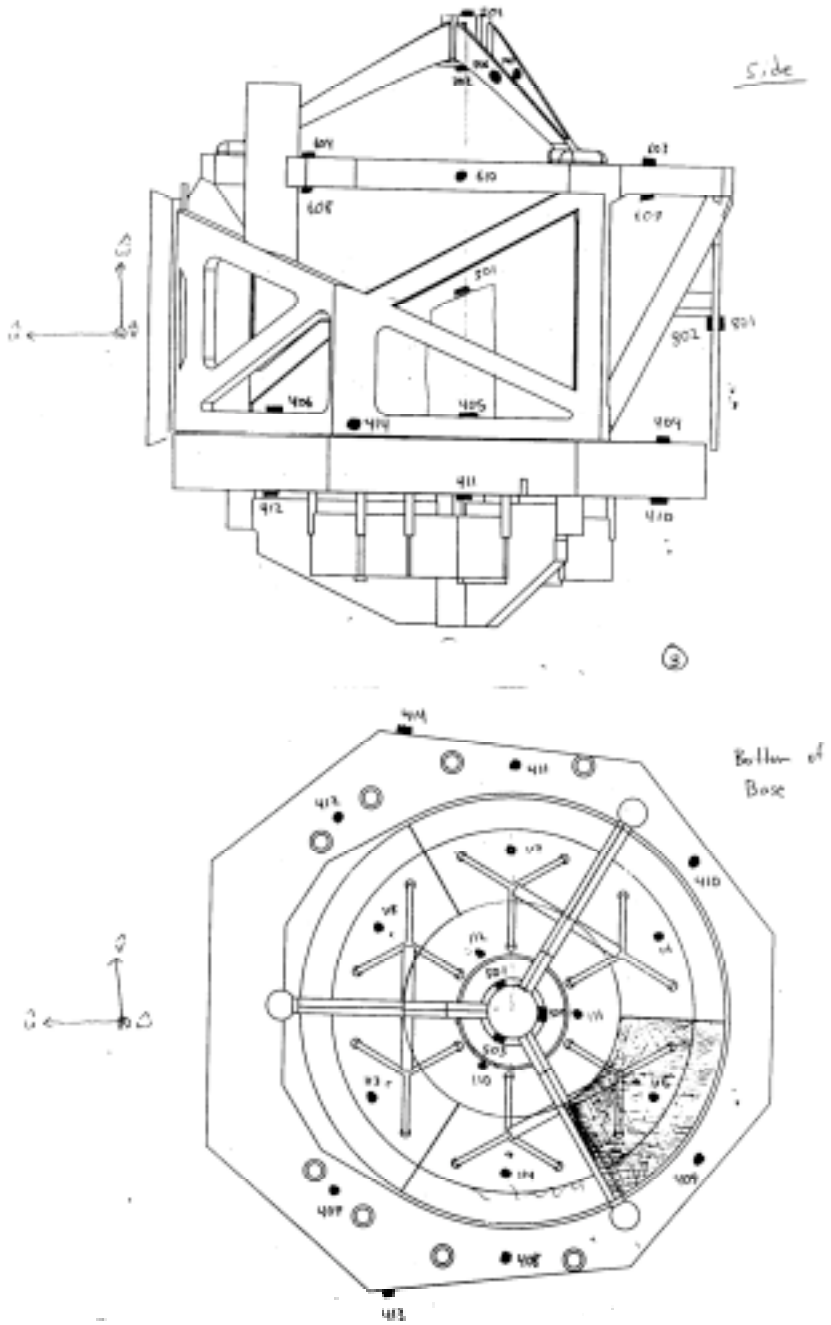


Figure 6E. TA Pressure Areas (Contd)

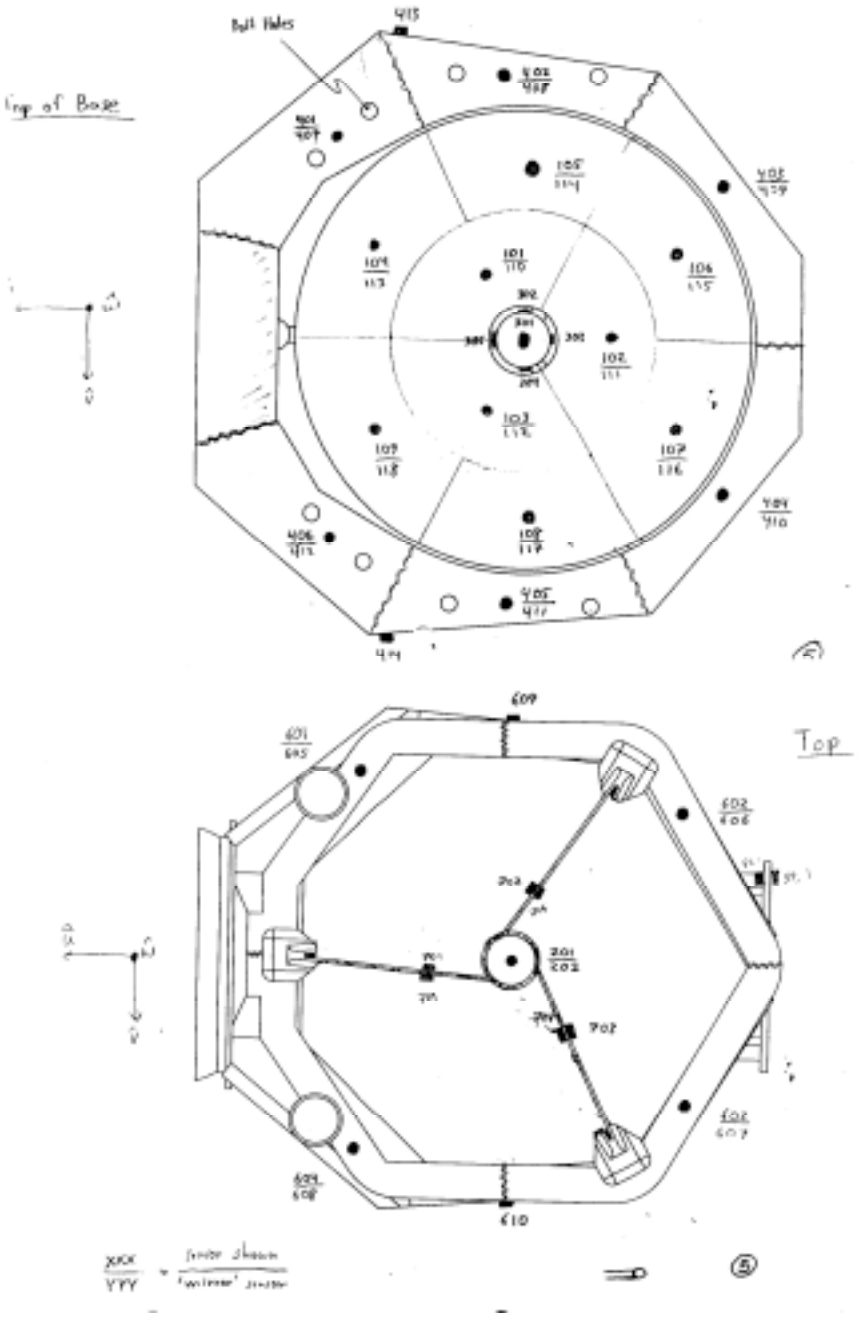


Figure 6F TA Area and Centroid Position Information

SOFIA V -- TA Sensor layout information								
Sensor	Sensor Loc.	Data Loc.	Distance to Centroid from bearing center (meters)			Projected Area (meters^2)		
No.	on TA	(Row No.)	L(u)	L(v)	L(w)	A(u)	A(v)	A(w)
Primary								
1	101	1	-2.286	-0.399	-0.555	0.000	0.000	-0.619
2	102	2	-2.975	0.000	-0.555	0.000	0.000	-0.619
3	103	3	-2.286	0.399	-0.555	0.000	0.000	-0.619
4	104	4	-1.597	-0.508	-0.555	0.000	0.000	-0.619
5	105	5	-2.540	-1.016	-0.555	0.000	0.000	-0.619
6	106	6	-3.411	-0.508	-0.555	0.000	0.000	-0.619
7	107	7	-3.411	0.508	-0.555	0.000	0.000	-0.619
8	108	8	-2.504	1.016	-0.555	0.000	0.000	-0.619
9	109	9	-1.597	0.508	-0.555	0.000	0.000	-0.619
10	110	10	-2.286	-0.399	-1.154	0.000	0.000	0.619
11	111	11	-2.975	0.000	-1.154	0.000	0.000	0.619
12	112	12	-2.286	0.399	-1.154	0.000	0.000	0.619
13	113	13	-1.597	-0.508	-1.154	0.000	0.000	0.619
14	114	14	-2.540	-1.016	-1.154	0.000	0.000	0.619
15	115	15	-3.411	-0.508	-1.154	0.000	0.000	0.619
16	116	16	-3.411	0.508	-1.154	0.000	0.000	0.619
17	117	17	-2.504	3.193	-1.154	0.000	0.000	0.619
18	118	18	-1.597	0.508	-1.154	0.000	0.000	0.619
Secondary								
19	201	19	-2.460	0.000	2.130	0.000	0.000	-0.129
20	202	20	-2.460	0.000	1.789	0.000	0.000	0.129
Tertiary								
21	301	21	-2.460	0.000	0.000	0.000	0.000	0.000
Base								
22	401	22	-1.089	-0.871	-0.791	0.000	0.000	-0.980
23	402	23	-2.431	-1.524	-0.791	0.000	0.000	-0.523
24	403	24	-3.701	-0.762	-0.791	0.000	0.000	-0.490
25	404	25	-3.701	0.762	-0.791	0.000	0.000	-0.490
26	405	26	-2.431	1.524	-0.791	0.000	0.000	-0.523
27	406	27	-1.089	0.871	-0.791	0.000	0.000	-0.980
28	407	28	-1.089	-0.871	-1.154	0.000	0.000	0.980
29	408	29	-2.431	-1.524	-1.154	0.000	0.000	0.523
30	409	30	-3.701	-0.762	-1.154	0.000	0.000	0.490
31	410	31	-3.701	0.762	-1.154	0.000	0.000	0.490
32	411	32	-2.431	1.524	-1.154	0.000	0.000	0.523

Figure 6F TA Area and Centroid Position Information (Contd)

33	412	33	-1.089	0.871	-1.154	0.000	0.000	0.980
34	413	34	-1.938	-1.756	-0.555	0.000	2.897	0.000
35	414	35	-1.938	1.756	-0.555	0.000	-2.897	0.000
Support								
36	501	36	-2.170	0.000	-1.524	-0.871	-1.509	0.000
37	502	37	-2.170	0.000	-1.524	1.742	0.000	0.000
38	503	38	-2.170	0.000	-1.524	-0.871	1.509	0.000
Headring								
39	601	39	-1.415	-1.016	1.143	0.000	0.000	-0.637
40	602	40	-3.556	-1.052	1.143	0.000	0.000	-0.658
41	603	41	-3.556	1.052	1.143	0.000	0.000	-0.658
42	604	42	-1.415	1.016	1.143	0.000	0.000	-0.637
43	605	43	-1.415	-1.016	0.951	0.000	0.000	0.637
44	606	44	-3.556	-1.052	0.951	0.000	0.000	0.658
45	607	45	-3.556	1.052	0.951	0.000	0.000	0.658
46	608	46	-1.415	1.016	0.951	0.000	0.000	0.637
47	609	47	-2.848	-1.676	0.635	0.000	1.779	0.000
48	610	48	-2.848	1.676	0.635	0.000	-1.779	0.000
Spider								
49	701	49	-1.705	0.073	1.604	0.000	0.274	0.000
50	702	50	-2.975	-0.726	1.604	-0.237	0.137	0.000
51	703	51	-2.975	0.653	1.604	0.237	0.137	0.000
52	704	52	-2.975	0.653	1.604	-0.237	-0.137	0.000
53	705	53	-1.705	0.073	1.604	0.000	-0.274	0.000
54	706	54	-2.975	-0.726	1.604	0.237	-0.137	0.000
Backplate								
55	801	55	0.000	0.000	0.000	0.471	0.000	0.000
56	802	56	0.000	0.000	0.000	-0.471	0.000	0.000

9.7 TELESCOPE CAVITY TRANSIENT AIR ENVIRONMENT

Note that Cavity Cool-down and Re-heat Environment is also described in Interface Document TA_AS_06, although TA_AS_06 does not address emergency descent reheat, as described in the "Maximum Cavity Reheat Environment" chart of Figure 7C. In case of discrepancies, the worst case environment will be design driving.

Figures 7A, 7B, and 7C show maximum rates of temperature changes in the cavity for airborne, pre-cool, and reheat phases of operation.

9.7.1 Cavity Airborne Environment – Figure 7A defines the temperature variation environment for which the telescope shall meet the image quality requirement. The chart should be interpreted as the maximum change in the ambient cavity air temperature over a given amount of time. The change in temperature is given as an absolute, meaning that the change can be either positive or negative from an initial state.

The slope of this curve at any point gives ΔTemp/minute. The temperature can change quite rapidly, but only for short periods of time. For example, it is possible for the temperature to change approximately 5° over 3 minutes, but that rate (1.67°C/minute) can be sustained only for relatively short periods of time. Over a 20 minute period, the average rate of temperature change would be a maximum of .625°C/minute.

9.7.2 Cavity Cool-down Environment – Figure 7B depicts the maximum cooldown environment that the telescope will be subject to. During the normal cooldown, the air in the cavity will follow the time profile shown in Figure 7B. The telescope and optics must be able to withstand this cooling environment without damage.

9.7.3 Cavity Re-heat Environment – Figure 7C depicts the re-heat environment that the telescope will be subject to. The top chart depicts the time history of the temperature during normal re-heat operations after a mission. The second chart depicts the maximum re-heating environment which would be encountered during an emergency descent scenario with the cavity door left open. The telescope and optics must survive both of these environments without sustaining damage.

Figure 7A. Cavity Air Environment – Airborne

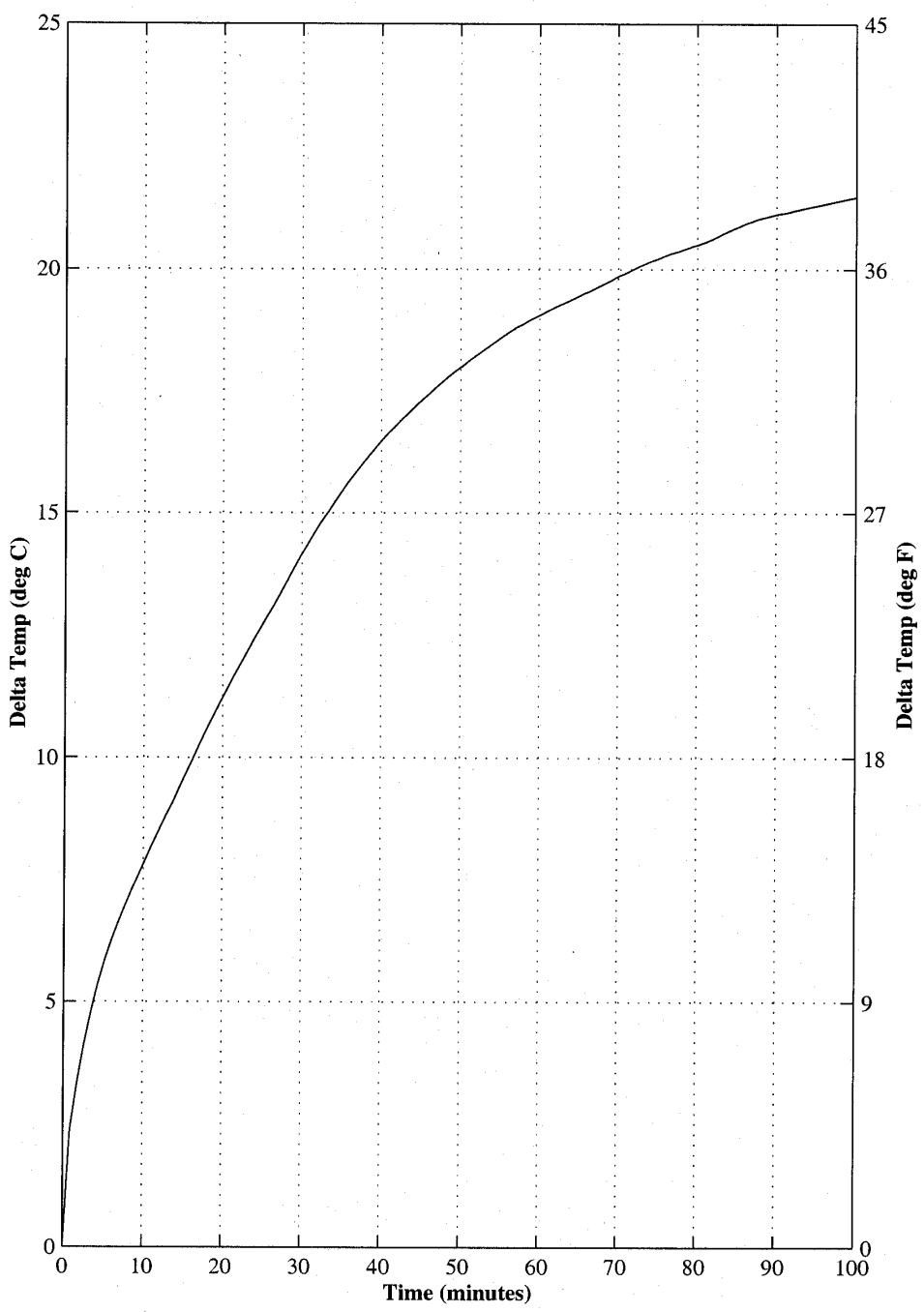


Figure 7B. Cavity Air Environment – Cool-Down Environment

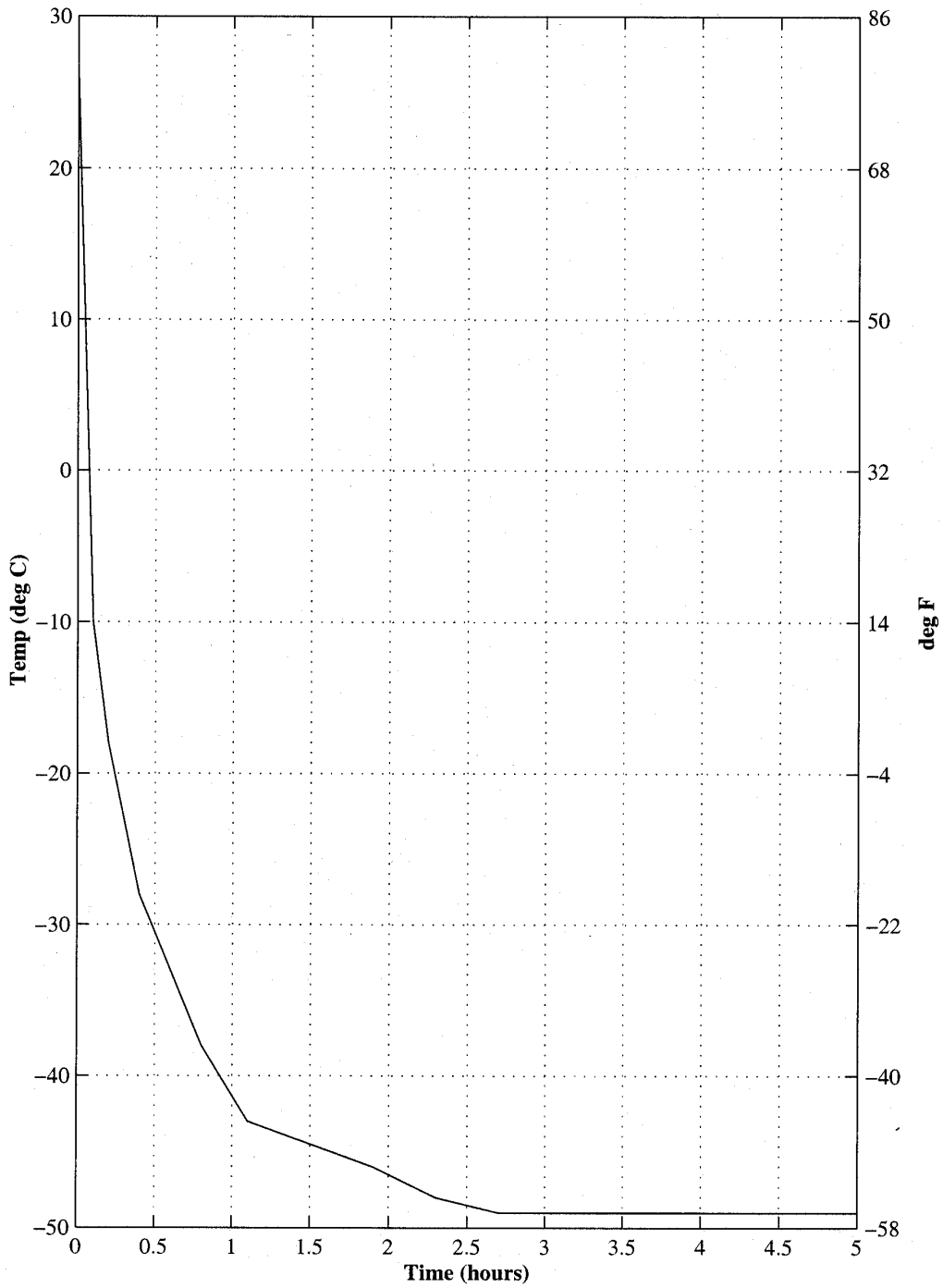
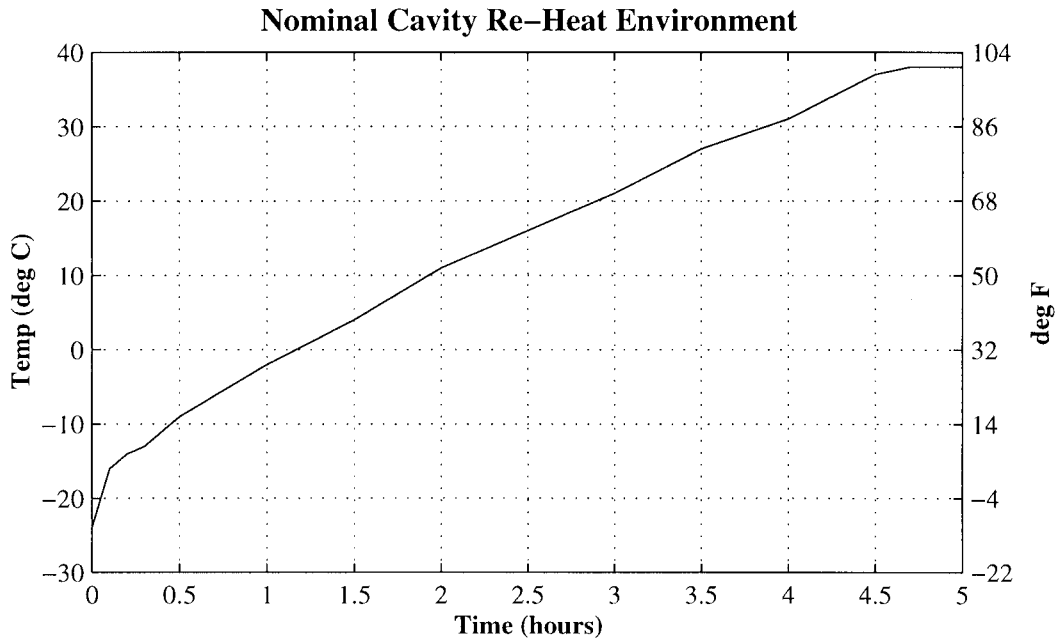
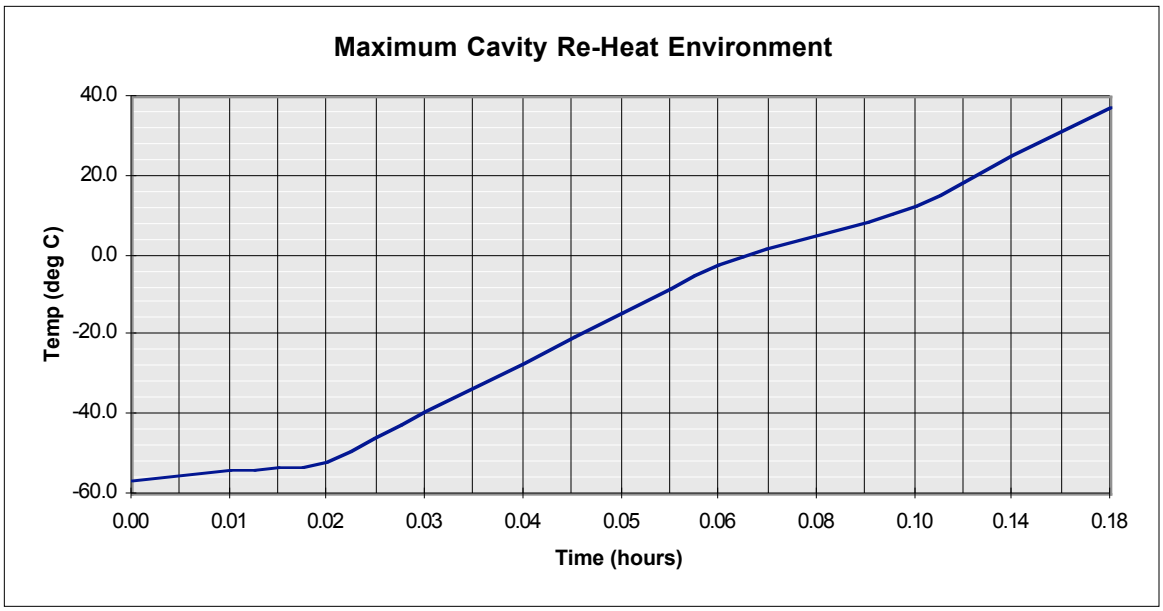


Figure 7C. Cavity Air Environment – Re-heat Environment





9.8 AIRCRAFT CABIN AND CAVITY STEADY-STATE AIR ENVIRONMENT

This section specifies the average steady-state air temperature and air pressure limits for components located within the cabin or the cavity. The temperatures specified do not include the temperatures near hot or cold surfaces or the temperatures within equipment racks, consoles, or confined spaces. The air temperature and air pressure limits are defined for the following conditions:

OPERATING ENVIRONMENT 1: Conditions for which all components shall fully operate and meet all of their performance requirements.

OPERATING ENVIRONMENT 2: Conditions for which all components, other than the vibration isolation system, shall fully operate, but with degradation allowed in the performance. These may occur on the ground during start-up or functional tests, or in flight in preparation for science observing. Cooling and heating requirements to achieve Operating Environment 1 conditions shall be worked in the appropriate ICDs.

OPERATING ENVIRONMENT 3: Conditions for which the TA components need not operate, other than to the degree necessary to protect the TA itself. These conditions could occur either in flight or on the ground and the TA would be exposed to such aircraft environments as aircraft motions, aeroacoustic loads, pressure across the pressure bulkhead, and flight temperature extremes. These conditions occur during aircraft operations such as towing, taxi, or ferry flights to and from maintenance locations where cavity and cabin temperature control would be limited, or during an observing flight when a failure occurs that results in a loss of primary power to TA and MCCS systems.

EXPOSURE: Non-operating (neither TA operations or flight operations) ground conditions for which components must survive undamaged in accordance with Figures 8A and 8B.

9.8.1 Cabin and Cavity Steady-state Temperature

Figure 8A shows the temperature ranges for the cabin and cavity at the conditions defined above:

Figure 8A. Steady-state Temperature Environment (degrees C)

CONDITION	CABIN	CAVITY	CABIN -CAVITY DIFFERENCE
OPERATING ENVIRONMENT 1	16 to 24	-54 to -12	28 to 78
OPERATING ENVIRONMENT 2			
a. ground operations	10 to 35	-40 to 35	-20 to 75
b. flight operations	12 to 28	-62 to 0	12 to 78
OPERATING ENVIRONMENT 3			
a. aircraft towing and taxiing operations	-10 to 55	-10 to 55	-40 to 65
b. aircraft flight operations	5 to 35	-62 to 55	-40 to 78
EXPOSURE:			
a. All components affecting Flight Safety	-40 to 85	-40 to 85	-40 to 40
b. Mech. components affecting TA Performance	-40 to 70	-40 to 70	-40 to 40
c. Electr. components affecting TA Performance	-30 to 55	-30 to 55	-40 to 40

9.8.2 Cabin and Cavity Steady Pressure Environment

Figure 8B shows the pressure ranges for the cabin and cavity at the conditions defined above:

Figure 8B. Steady Pressure Environment (psia)

CONDITION	ABSOLUTE CABIN	ABSOLUTE CAVITY	CABIN-CAVITY DIFFERENTIAL
OPERATING ENVIRONMENT 1	11.0 to 15.0	2.0 to 4.0	7.0 to 9.4
OPERATING ENVIRONMENT 2	11.0 to 15.0	2.0 to 15.0	-0.25 to 9.4
OPERATING ENVIRONMENT 3	11.0 to 15.0	2.0 to 15.0	-0.25 to 9.4
EXPOSURE	2.0 to 27.2*	2.0 to 15.0	-0.25 to 12.5*

* This exposure pressure is needed for occasional ground leak tests of the observatory cabin. TA components which are vulnerable to this absolute pressure exposure may be temporarily removed from the observatory for these tests.

Note: Assume Nz=1.0, Nx=Ny=0.0

9.9 ELECTROMAGNETIC INTERFERENCE (EMI) ENVIRONMENT

Figures 9A, 9B, 9C, and 9D give mappings of the radiated and naturally induced Electromagnetic Interference environments within the aircraft cabin and cavity (TBD by AS, TA and MCCS developers). (Note: conducted EMI environments are covered in the electrical power/communications ICDs).

Figure 9A. Radiated EMI Environment – Cabin

TBD by AS, TA, and MCCS Developers

Figure 9B. Radiated EMI Environment – Cavity

TBD by AS, TA, and MCCS Developers

Figure 9C. Naturally Induced EMI Environment – Cabin

TBD by AS, TA, and MCCS Developers

Figure 9D. Naturally Induced EMI Environment – Cavity

TBD by AS, TA, and MCCS Developers

10.0 GLOBAL INTERFACES

10.1 INTRODUCTION

Global Interfaces involve more than two system elements, and must therefore be treated differently. All interfaces that involve only two system elements are located in Section 11.0. Guideline descriptions of the ICDs shown herein are provided for guidance in preparing initial ICD issues. Actual ICDs should reflect the actual design interfaces as necessary and may evolve as designs mature during development.

10.1.1 Master Interface Control Document (ICD) List

Interface Number: GLOBAL_01
Responsible for Documentation: U.S. Prime Contractor

10.1.1.1 Description – The master ICD list will be used to track the status of all ICDs for the SOFIA project. All the interfaces defined in SOF-1030 will be part of this list and the associated ICDs in which they are controlled will be referenced. In addition, information on the current status and plan of the interfaces will be given.

10.1.1.2 Interface Contents – The following items, as a minimum, will be controlled as part of this interface and shall appear in the ICD controlling this interface:

(a) For each interface, the ICD which is being used to control that interface will be listed.
(b) For each interface, the current status of its definition will be given.
(c) The current point of contact for each interface shall be included.

10.1.2 Airborne Facility Weight and Balance

Interface Number: GLOBAL_02
Responsible for Documentation: U.S. Prime Contractor

This Interface Number has been deleted.

10.1.3 SOFIA LAN Architecture

Interface Number: GLOBAL_03
Responsible for Documentation: U.S. Prime Contractor

10.1.3.1 Description – The purpose of this interface is to define the standard LAN architecture(s) used on the facility. This interface is documented in the TA_MCCS_F and the TA_MCCS_P ICDs.

10.1.3.2 Interface Contents – The following items, as a minimum, will be controlled as part of this interface and shall appear in the ICD controlling this interface:

(a) The protocols and software used for the airborne LAN.
(b) The network layout for the airborne facility.

10.1.4 SOFIA Layout Of Personnel Accommodations (LOPA)

Interface Number: GLOBAL_04
Responsible for Documentation: U.S. Prime Contractor

10.1.4.1 Description – The LOPA will be used for the initial partitioning of space on board the aircraft. The SOFIA project office will work with each of the system elements to define the space needed for equipment and modifications on board the aircraft.

10.1.4.2 Interface Contents – The following items, as a minimum, will be controlled as part of this interface and shall appear in the ICD controlling this interface:

(a) The spatial envelopes for all on board equipment and modifications.
(b) Allocation of space for deployment equipment.
(c) The spatial envelopes allocated to all equipment that is designated for mounting or transport in the cargo lobes.
(d) The spatial envelopes available for the installation and removal of the SI.
(e) The spatial envelopes available for the installation and removal of all equipment in the aircraft cabin.

10.1.5 SOFIA Coordinate Systems

Interface Number: GLOBAL_05
Responsible for Documentation: U.S. Prime Contractor

10.1.5.1 Description – This interface controls the reference coordinate systems used in the aircraft and in the ground support facility.

10.1.5.2 Interface Contents – The following items, as a minimum, will be controlled as part of this interface and shall appear in the ICD controlling this interface:

(a) The definition of the aircraft coordinate system.
(b) The definition of the telescope coordinate system and its relationship to the aircraft.
(c) The definition of the ground support facility coordinate system.

10.1.6 Commercial Off-the-Shelf (COTS) Equipment

Interface Number: GLOBAL_06
Responsible for Documentation: U.S. Prime Contractor

10.1.6.1 Description – To maintain as much commonality as possible in the facility, the Contractor will maintain a list of agreed-to COTS equipment for use in the facility. This list covers both hardware and software.

10.1.6.2 Interface Contents – The following items, as a minimum, will be controlled as part of this interface and shall appear in the ICD controlling this interface.

(a) Agreed-to COTS hardware for each function specified in the ICD.
(b) Agreed-to COTS software for each function specified in the ICD.

10.1.7 Aircraft Floor Loading Interface Requirements

Interface Number: GLOBAL_07
Responsible for Documentation: U.S. Prime Contractor

10.1.7.1 Description – During integration and testing, and during operations, it will be necessary for all system elements to bring equipment on and off of the aircraft. This section controls the interface for loading of the aircraft floor. The floor loading for any equipment permanently mounted to the floor will be handled in a separate interface.

10.1.7.2 Interface Contents – The following items, as a minimum, will be controlled as part of this interface and shall appear in the ICD controlling this interface:

(a) The type of equipment installed temporarily aboard the AS, including size, mass properties, and locations.
(b) Limits on the concentration of loading for all equipment temporarily installed aboard the aircraft, or transported through the aircraft.

10.1.8 Stray Light Control and Background Noise Suppression

Interface Number: GLOBAL_08
Responsible for Documentation: US Prime Contractor

10.1.8.1 Description – This interface pertains to design elements of the cavity and telescope which could affect the amount of stray light reaching the focal plane.

10.1.8.2 Interface Contents – The following items, as a minimum, will be controlled as part of this interface and shall appear in the ICD controlling this interface.

(a) The dynamic motions of the telescope and cavity relative to the focal plane
(b) The surface coatings and materials used in the cavity and on the telescope.
(c) The definition of specific design elements which could affect stray light such as shaping of the cavity and the telescope.

10.1.9 Science Instrument Envelope

Interface Number: GLOBAL_09
Responsible for Documentation: US Prime Contractor

10.1.9.1 Description – This interface controls the science instrument spatial interface with the aircraft system and telescope assembly.

10.1.9.2 Interface Contents – The following items, as a minimum, will be controlled as part of this interface and shall appear in the ICD controlling this interface.

(a) An SI static envelope outside of which SI components shall not extend, and into which AS and TA components shall not protrude, applicable for the full range of motion the TA experiences in the AS during TA operation. This envelope is fixed to the TA, which must support and locate it in a particular position relative to the IR beam, focal plane, and TA elevation position.

(b) An SI total dynamic envelope into which permanently mounted AS components shall not extend this envelope is fixed to the AS and large enough to accommodate the SI static envelope when the TA experiences its full range of motions and deflection in the aircraft, and includes extra space for personnel safety and access.

Note that the SI envelope affects both the AS and TA volume, thus making this a Global ICD.

11.0 SYSTEM INTERFACES

11.1 TELESCOPE ASSEMBLY/AIRCRAFT SYSTEM INTERFACES

11.1.1 Aircraft Cavity Pressure Bulkhead/Telescope Assembly Interface

Interface Number: TA_AS_01
Responsible for Documentation: U.S. Prime Contractor

11.1.1.1 Description – This interface controls the mounting of the telescope on the cavity pressure bulkhead, also known as the forward bulkhead. The baseline design assumes that the primary interface will be between the bulkhead and the telescope vibration isolation system (VIS). If the telescope includes a pressure compensation system such as a pressure plenum, the mounting of that system to the bulkhead will also be controlled as part of this interface.

11.1.1.2 Interface Contents – The following items, as a minimum, will be controlled as part of this interface and shall appear in the ICD controlling this interface:

(a) The mounting interface between the TA vibration isolation system (VIS) and the pressure bulkhead.
(b) The mounting interface between the TA pressure compensation system (if required) and the pressure bulkhead.
(c) The mounting interface between the TA pressure seal and the pressure bulkhead.
(d) The mounting of any TA-provided attitude measurement system on the aircraft and the routing of any associated cables.

(e) The location of the interface mounting points relative to the rest of the aircraft.
(f) The mass and center of gravity (c.g.) limits of the part of the Telescope Assembly attached to the forward bulkhead.
(g) The maximum heat conduction rate across the mount between the bulkhead and the TA, and the interface temperature limits.
(h) The maximum allowable deflections and angular displacements of the bulkhead mounts during operating, non-operating, and emergency environments.

11.1.2 Aircraft Cavity Aft Bulkhead/Telescope Assembly Braking/Locking Subsystem Interface

Interface Number: TA_AS_02
Responsible for Documentation: U.S. Prime Contractor

11.1.2.1 Description – This interface controls the mounting of the Telescope Assembly braking/locking system to the Aircraft System aft bulkhead. This interface will only be necessary if the Telescope Assembly requires the use of the aft bulkhead in caging/centering of the telescope. If needed, this interface will control the interface geometry, attachment and sealing provisions, dimensional tolerances, capture envelope, mass and c.g. limits, and other information needed to specify the interface requirements.

11.1.2.2 Interface Contents – The following items, as a minimum, will be controlled as part of this interface and shall appear in the ICD controlling this interface:

(a) The mounting interface between the TA caging/locking/centering mechanism and the aft bulkhead.
(b) The location of the interface mounting points relative to the rest of the aircraft.
(c) The mass and center of gravity (c.g.) limits of the caging mechanism.
(d) The limits of loading imposed by the telescope on the aft bulkhead when caged, under all applicable environments.
(e) The maximum heat conduction rate across the mount between the bulkhead and the caging mechanism, and the interface temperature limits.
(f) The maximum allowable deflections and angular displacements of the bulkhead mounts during operating, non-operating, and emergency environments.
(g) Transmissibility of aircraft loading to TA.

11.1.3 Aircraft System/Telescope Assembly Cable Load Alleviation Device Interface

Interface Number: TA_AS_03
Responsible for Documentation: Telescope Assembly Contractor

11.1.3.1 Description – This interface controls the mounting of the TA-supplied cable load alleviation device to the inside of the aircraft cabin. The purpose of the cable load alleviation device is to minimize the loads imparted to the TA due to power, signal, and vacuum lines connected to the TA.

11.1.3.2 Interface Contents – The following items, as a minimum, will be controlled as part of this interface and shall appear in the ICD controlling this interface:

(a) The mounting interface between the TA cable load alleviation device and the Aircraft System fuselage/bulkhead.
(b) The location of the interface mounting points relative to the rest of the aircraft.
(c) The locations where the power, signal, and video lines enter and leave the cable load alleviation device.
(d) The mass and center of gravity (c.g.) properties of the cable load alleviation device, as burdened by the cabling.
(e) Dynamic loads of the devices/cables on the mount, up to emergency limits.
(f) Load of aircraft upon device cables.
(g) Spatial envelope for cable load alleviation device, including cables.

11.1.4 Aircraft System/Telescope Assembly Installation and Removal Interface Requirements

Interface Number: TA_AS_04
Responsible for Documentation: U.S. Prime Contractor

11.1.4.1 Description – This interface controls the installation and removal of all telescope sub-assemblies, except the optical assemblies which are covered under their own interface. This interface will cover mounting of the Telescope Assembly installation and removal equipment to aircraft hardpoints, as well as the procedures used for installation and removal. The spatial envelopes needed for installation and removal of equipment will also be included.

11.1.4.2 Interface Contents – The following items, as a minimum, will be controlled as part of this interface and shall appear in the ICD controlling this interface:

(a) The mounting interface between the TA installation and removal equipment and the Aircraft System fuselage and bulkheads.
(b) The location of the interface mounting points relative to the rest of the aircraft.
(c) The mass and center of gravity (c.g.) limits of equipment mounted to the aircraft at the mounting points.
(d) The limits of loading imposed by the telescope on the mounting points during installation and removal.
(e) The maximum allowable deflections and angular displacements of the aircraft mounts during installation and removal.
(f) A detailed description of the procedures for installation and removal of telescope assemblies to the aircraft.
(g) Spatial envelopes between the telescope assemblies and the aircraft structure during installation and removal of equipment.

11.1.5 Aircraft Cavity/Telescope Optical Assembly Installation and Removal Interface Requirements

Interface Number: TA_AS_05
Responsible for Documentation: U.S. Prime Contractor

11.1.5.1 Description – This interface will cover installation and removal of all telescope optical assemblies (primary mirror, secondary mirror, tertiary mirror, imagers), including the mounting of any special equipment needed for this purpose. The ICD will describe the procedures used for installation and will also control the spatial envelopes needed for installation and removal of the optical assemblies.

11.1.5.2 Interface Contents – The following items, as a minimum, will be controlled as part of this interface and shall appear in the ICD controlling this interface:

(a) The mounting interface between the TA optical assemblies installation and removal equipment and the Aircraft System fuselage and bulkheads.
(b) The location of the interface mounting points relative to the rest of the aircraft.
(c) The mass and center of gravity (c.g.) limits of equipment mounted to the aircraft at the mounting points.
(d) The limits of loading imposed by the telescope on the mounting points during installation and removal.
(e) The maximum allowable deflections and angular displacements of the aircraft mounts during installation and removal.
(f) A detailed description of the procedures for installation and removal of telescope optical assemblies.
(g) Spatial envelopes between the telescope optical assemblies and the aircraft structure during installation and removal of equipment.

11.1.6 Aircraft Cavity ECS/Telescope Assembly Interface

Interface Number: TA_AS_06
Responsible for Documentation: U.S. Prime Contractor

11.1.6.1 Description – This interface defines the attachment and/or location interfaces for (TBD) TA flow aid devices mounted in the cavity, including any necessary cables, air/pneumatic lines, routing, geometry, tolerances, etc. The flow-aid devices described here would be used by the Telescope Assembly to aid in the cool-down of the telescope structure and/or to maintain an even temperature distribution over the TA during flight. There is currently no requirement that additional flow-aid devices to be installed. This interface is a place-holder in case such equipment is deemed necessary by the Telescope Assembly.

11.1.6.2 Interface Contents – The following items, as a minimum, will be controlled as part of this interface and shall appear in the ICD controlling this interface:

(a) The mounting interface between the TA flow aid devices and the Aircraft System fuselage and bulkheads.
(b) The mounting interface between any air-supply lines or electrical lines needed by the flow-aid devices and the aircraft structure.

(c) The location of the interface mounting points relative to the rest of the aircraft.
(d) The requirements for compressed air needed by the flow-aid devices.
(e) The mass and center of gravity (c.g.) limits of the flow-aid devices mounted on the aircraft.
(f) Any special TA-defined heating and cooling requirements to be provided by the cavity ECS.

11.1.7 Aircraft System/TA Rotation Isolation Subsystem Auxiliary Equipment Interface

Interface Number: TA_AS_07
Responsible for Documentation: U.S. Prime Contractor

11.1.7.1 Description – This interface defines the mounting of any additional support equipment needed by the TA Rotation Isolation Subsystem (RIS), such as air compressors. The interface will also include the routing of any needed lines or cables between the support equipment and the RIS, such as pneumatic lines.

11.1.7.2 Interface Contents – The following items, as a minimum, will be controlled as part of this interface and shall appear in the ICD controlling this interface:

(a) The mounting interface between the TA RIS auxiliary equipment and the aircraft.
(b) The location of the interface mounting points relative to the rest of the aircraft.
(c) The lengths and mounting of lines and cables routed by the AS.
(d) The mass and center of gravity (c.g.) limits of the RIS auxiliary equipment.
(e) Spatial envelopes between the RIS auxiliary equipment and the aircraft structure during installation of equipment.
(f) Any overboard venting requirements of the RIS auxiliary equipment.

11.1.8 Aircraft System/Telescope Assembly Collimator Interface

Interface Number: TA_AS_08
Responsible for Documentation: U.S. Prime Contractor

11.1.8.1 Description – This interface controls the mounting of the TA collimator to the aircraft. The collimator will be used for the initial alignment of the SOFIA optics. After the integration and test phase, the collimator will be needed only occasionally.

11.1.8.2 Interface Contents – The following items, as a minimum, will be controlled as part of this interface and shall appear in the ICD controlling this interface:

(a) The mounting interface between the TA collimator and the Aircraft System.
(b) The location of the interface mounting points relative to the rest of the aircraft.
(c) The mass and center of gravity (c.g.) limits of the collimator.
(d) Alignment requirements of the collimator, including the maximum allowable deflections and angular displacements of the aircraft mounts with the collimator attached.
(e) A detailed description of the procedures for installation and removal of the TA collimator to the aircraft.
(f) Spatial envelopes between the telescope assemblies and the aircraft structure during installation and removal of equipment.

(g) Equipment safety interlocks (e.g., to prevent cavity door from closing on collimator).

11.1.9 Aircraft Cavity/Telescope Assembly Envelope

Interface Number: TA_AS_09
Responsible for Documentation: U.S. Prime Contractor

11.1.9.1 Description – This interface defines the clearance envelope between the Telescope Assembly and the Aircraft cavity for both static and dynamic cases. The dynamic case includes the operational ranges of both the telescope and the cavity door along with deflections due to travel on the vibration isolation system.

The interface also controls the spatial relationship between the telescope and the aperture that is needed to meet the non-vignetting requirements defined in SOF-1010 and SOF-1011. The non-vignetting requirements include requirements for the range of telescope elevation travel as well as instantaneous non-vignetting requirements.

11.1.9.2 Interface Contents – The following items, as a minimum, will be controlled as part of this interface and shall appear in the ICD controlling this interface:

(a) The spatial envelope in the cavity available to the telescope during operations.
(b) The spatial envelope in the cavity available to the aircraft during operations.
(c) The area available on the bulkheads for mounting of equipment.
(d) The spatial relationship interface between the telescope and the aperture for purposes of meeting the instantaneous non-vignetting requirements.
(e) The spatial relationship interface between the telescope, the cavity door, and the fuselage cutout for purposes of meeting the requirements of non-vignetting over the specified travel range defined in SOF-1011.

11.1.10 Aircraft Cabin/Telescope Assembly Envelope

Interface Number: TA_AS_10
Responsible for Documentation: U.S. Prime Contractor

11.1.10.1 Description – This interface defines the clearance envelope between the Telescope Assembly and the Aircraft cabin for both static and dynamic cases. The dynamic case includes the operational range of the telescope along with deflections due to travel on the vibration isolation system. This clearance envelope is limited to the region in the cabin which is outside of the Nasmyth tube and aft (in the aircraft) of the vertical plane containing the SI-to-TA mounting surface.

11.1.10.2 Interface Contents – The following items, as a minimum, will be controlled as part of this interface and shall appear in the ICD controlling this interface:

(a) The spatial envelope in the cabin available to the telescope during operations.
(b) The spatial envelope in the cabin available to the aircraft during operations.
(c) The area available on the cabin side of the pressure bulkhead for mounting of equipment.

11.1.11 Telescope Assembly/Aircraft System Exhaust Tube and Vacuum Line(s) Interface

Interface Number: TA_AS_11
Responsible for Documentation: U.S. Prime Contractor

11.1.11.1 Description – The exhaust tube is used to evacuate the Nasmyth tube and SI by attaching a tube to an external fuselage port in the vicinity of a low static pressure. The purpose of the exhaust tube is to ensure that air does not stagnate in the Nasmyth tube or SI. The vacuum lines are used by the SI for pulling a vacuum on the instrument and/or associated dewar. The aircraft system supplies both lines up to the cable load alleviation device. The TA supplies the lines from the cable load alleviation device to the SI interface. This interface number controls the connection between the TA and AS portions of the exhaust tube and vacuum line(s).

11.1.11.2 Interface Contents – The following items, as a minimum, will be controlled as part of this interface and shall appear in the ICD controlling this interface:

(a) The location of the connections.
(b) The type of connections.
(c) Properties of the exhaust tube and vacuum line(s) such as stiffness and minimum bend radii.

11.1.12 Aircraft System/Telescope Assembly Power Interface

Interface Number: TA_AS_12
Responsible for Documentation: U.S. Prime Contractor

11.1.12.1 Description The Aircraft System will supply raw electrical power for use by the Telescope Assembly (and other elements of the observatory). This ICD will control the specific parameters of how and where the power is supplied to the TA by the MCCS. Raw electrical power from the aircraft will be 200/115 volts, Y-connected, 400 Hz with characteristics standard to the electrical system of a Boeing 747SP aircraft.

11.1.12.2 Interface Contents – The following items, as a minimum, will be controlled as part of this interface and shall appear in the ICD controlling this interface:

(a) The location where power is supplied to the TA, and the type of connection used.
(b) The amount of power supplied to the TA.
(c) The type of power supplied to the TA.
(d) The quality of power supplied to the TA.

11.2 TELESCOPE ASSEMBLY/MISSION CONTROLS AND COMMUNICATIONS SYSTEM (MCCS)

11.2.1 Primary Mirror/Tertiary Mirror Electronics Subsystem/MCCS Interface

Interface Number: TA_MCCS_01
Responsible for Documentation: U.S. Prime Contractor

11.2.1.1 Description – This interface is a place holder for any (TBD) primary mirror/tertiary mirror electronics. This interface controls the functional interfaces between the MCCS and the TA primary mirror/tertiary mirror electronics and the physical mounting interface of the electronics into the MCCS equipment racks. Also included is the interface for the associated cables that will be routed by the MCCS. The MCCS will supply and route all inter-system cables (i.e., between the MCCS, AS, TA, SSMO, or SI). All intra-system cables will be supplied by that system and will only be routed by the MCCS. Note that even though the interface is identified separately, it is acceptable for all of the TA communications interfaces with the MCCS to take place over one physical connection. This document does not require that a separate communications interface be established with the primary mirror/tertiary mirror electronics. This interface is documented in the TA_MCCS_F and the TA_MCCS_P ICDs.

11.2.1.2 Interface Contents – The following items, as a minimum, will be controlled as part of this interface and shall appear in the ICD controlling this interface:

(a) The mounting interface between the TA primary mirror/tertiary mirror electronics and the MCCS equipment racks.
(b) The mass and center of gravity (c.g.) limits of the TA primary mirror/tertiary mirror electronics.
(c) All information necessary for the routing of TA cables by the MCCS, including the number and types of cables associated with the electronics, minimum bend radius, length of cables, cable identification numbers, etc..
(d) The connection interface between TA cables and MCCS cables.
(e) The communications interface with the TA primary mirror/tertiary mirror electronics, including parameters for monitoring, control, and annunciation.

11.2.2 Thermal Control Subsystem/MCCS Interface

Interface Number:	TA_MCCS_02
Responsible for Documentation:	U.S. Prime Contractor

11.2.2.1 Description – This interface is a place holder for any (TBD) thermal control system provided by the TA. This interface controls the functional interfaces between the MCCS and the TA thermal control system and the physical mounting interface of the electronics into the MCCS equipment racks. Also included is the interface for the associated cables that will be routed by the MCCS. The MCCS will supply and route all inter-system cables (i.e., between the MCCS, AS, TA, SSMO, or SI). All intra-system cables will be supplied by that system and will only be routed by the MCCS. Note that even though the interface is identified separately, it is acceptable for all of the TA communications interfaces with the MCCS to take place over one physical connection. This document does not require that a separate communications interface be established with the thermal control subsystem. This interface is documented in the TA_MCCS_F and the TA_MCCS_P ICDs.

11.2.2.2 Interface Contents – The following items, as a minimum, will be controlled as part of this interface and shall appear in the ICD controlling this interface:

(a) The mounting interface between the TA thermal control subsystem electronics and the MCCS equipment racks.

(b) The mass and center of gravity (c.g.) limits of the TA thermal control subsystem electronics.
(c) All information necessary for the routing of TA cables by the MCCS, including the number and types of cables associated with the electronics, minimum bend radius, length of cables, etc.
(d) The connection interface between TA cables and MCCS cables.
(e) The communications interface with the TA thermal control subsystem electronics, including parameters for monitoring, control, and annunciation.

11.2.3 Secondary Mirror Control Subsystem/MCCS Interface

Interface Number: TA_MCCS_03
Responsible for Documentation: U.S. Prime Contractor

11.2.3.1 Description – This interface controls the functional interfaces between the MCCS and the TA secondary mirror control subsystem electronics and the physical mounting interface of the electronics into the MCCS equipment racks. Also included is the interface for the associated cables that will be routed by the MCCS. The MCCS will supply and route all inter-system cables (i.e., between the MCCS, AS, TA, SSMO, or SI). All intra-system cables will be supplied by that system and will only be routed by the MCCS. Note that even though the interface is identified separately, it is acceptable for all of the TA communications interfaces with the MCCS to take place over one physical connection. This document does not require that a separate communications interface be established with the secondary mirror control subsystem electronics. This interface is documented in the TA_MCCS_F and the TA_MCCS_P ICDs.

11.2.3.2 Interface Contents – The following items, as a minimum, will be controlled as part of this interface and shall appear in the ICD controlling this interface:

(a) The mounting interface between the TA secondary mirror control subsystem electronics and the MCCS equipment racks.
(b) The mass and center of gravity (c.g.) limits of the TA secondary mirror control subsystem electronics.
(c) All information necessary for the routing of TA cables by the MCCS, including the number and types of cables associated with the electronics, minimum bend radius, length of cables, etc.
(d) The connection interface between TA cables and MCCS cables.
(e) The communications interface with the TA secondary mirror control subsystem electronics, including parameters for monitoring, control, and annunciation.

11.2.4 Rotational Drive Control Subsystem/MCCS Interface

Interface Number: TA_MCCS_04
Responsible for Documentation: U.S. Prime Contractor

11.2.4.1 Description – This interface controls the functional interfaces between the MCCS and the TA rotational drive control subsystem electronics and the physical mounting interface of the electronics into the MCCS equipment racks. Also included is the interface for the associated cables that will be routed by the MCCS. The MCCS will supply and route all inter-system cables (i.e., between the MCCS, AS, TA, SSMO, or

SI). All intra-system cables will be supplied by that system and will only be routed by the MCCS. Note that even though the interface is identified separately, it is acceptable for all of the TA communications interfaces with the MCCS to take place over one physical connection. This document does not require that a separate communications interface be established with the rotational drive control subsystem electronics. This interface is documented in the TA_MCCS_F and the TA_MCCS_P ICDs.

11.2.4.2 Interface Contents – The following items, as a minimum, will be controlled as part of this interface and shall appear in the ICD controlling this interface:

(a) The mounting interface between the TA rotational drive control subsystem electronics and the MCCS equipment racks.
(b) The mass and center of gravity (c.g.) limits of the TA rotational drive control subsystem electronics.
(c) All information necessary for the routing of TA cables by the MCCS, including the number and types of cables associated with the electronics, minimum bend radius, length of cables, etc.
(d) The connection interface between TA cables and MCCS cables.
(e) The communications interface with the TA rotational drive control subsystem electronics, including parameters for monitoring, control, and annunciation.

11.2.5 Tracking Control Subsystem/MCCS Interface

Interface Number: TA_MCCS_05
Responsible for Documentation: U.S. Prime Contractor

11.2.5.1 Description – This interface controls the functional interfaces between the MCCS and the TA tracking control subsystem and the physical mounting interface of the electronics into the MCCS equipment racks or consoles. Also included is the interface for the associated cables that will be routed by the MCCS. The MCCS will supply and route all inter-system cables (i.e., between the MCCS, AS, TA, SSMO, or SI). All intra-system cables will be supplied by that system and will only be routed by the MCCS. Note that even though the interface is identified separately, it is acceptable for all of the TA communications interfaces with the MCCS to take place over one physical connection. This document does not require that a separate communications interface be established with the tracking control subsystem. This interface is documented in the TA_MCCS_F and the TA_MCCS_P ICDs.

11.2.5.2 Interface Contents – The following items, as a minimum, will be controlled as part of this interface and shall appear in the ICD controlling this interface:

(a) The mounting interface between the TA tracking control subsystem and the MCCS equipment racks or consoles.
(b) The mass and center of gravity (c.g.) limits of the TA tracking control subsystem electronics.
(c) All information necessary for the routing of TA cables by the MCCS, including the number and types of cables associated with the electronics, minimum bend radius, length of cables, etc.
(d) The connection interface between TA cables and MCCS cables.

(e) The communications interface with the TA tracking control subsystem electronics, including parameters for monitoring, control, and annunciation.
(f) The signal interfaces for any non-LAN connections between the TA tracking control system and the MCCS.

11.2.6 Balancing Control Subsystem/MCCS Interface

Interface Number: TA_MCCS_06
Responsible for Documentation: U.S. Prime Contractor

11.2.6.1 Description – This interface controls the functional interfaces between the MCCS and the TA balancing control subsystem electronics and the physical mounting interface of the electronics into the MCCS equipment racks. Also included is the interface for the associated cables that will be routed by the MCCS. The MCCS will supply and route all inter-system cables (i.e., between the MCCS, AS, TA, SSMO, or SI). All intra-system cables will be supplied by that system and will only be routed by the MCCS. Note that even though the interface is identified separately, it is acceptable for all of the TA communications interfaces with the MCCS to take place over one physical connection. This document does not require that a separate communications interface be established with the balancing control subsystem electronics. This interface is documented in the TA_MCCS_F and the TA_MCCS_P ICDs.

11.2.6.2 Interface Contents – The following items, as a minimum, will be controlled as part of this interface and shall appear in the ICD controlling this interface:

(a) The mounting interface between the TA balancing control subsystem electronics and the MCCS equipment racks.
(b) The mass and center of gravity (c.g.) limits of the TA balancing control subsystem electronics.
(c) All information necessary for the routing of TA cables by the MCCS, including the number and types of cables associated with the electronics, minimum bend radius, length of cables, etc.
(d) The connection interface between TA cables and MCCS cables.
(e) The communications interface with the TA balancing control subsystem electronics, including parameters for monitoring, control, and annunciation.

11.2.7 Braking/Caging Control Subsystem/MCCS Interface

Interface Number: TA_MCCS_07
Responsible for Documentation: U.S. Prime Contractor

11.2.7.1 Description – This interface controls the functional interfaces between the MCCS and the TA braking/caging control subsystem electronics and the physical mounting interface of the electronics into the MCCS equipment racks. Also included is the interface for the associated cables that will be routed by the MCCS. The MCCS will supply and route all inter-system cables (i.e., between the MCCS, AS, TA, SSMO, or SI). All intra-system cables will be supplied by that system and will only be routed by the MCCS. Note that even though the interface is identified separately, it is acceptable for all of the TA communications interfaces with the MCCS to take place over one physical connection. This document does not require that a separate communications

interface be established with the braking/caging control subsystem electronics. This interface is documented in the TA_MCCS_F and the TA_MCCS_P ICDs.

11.2.7.2 Interface Contents – The following items, as a minimum, will be controlled as part of this interface and shall appear in the ICD controlling this interface:

(a) The mounting interface between the TA braking/caging control subsystem electronics and the MCCS equipment racks.
(b) The mass and center of gravity (c.g.) limits of the TA braking/caging control subsystem electronics.
(c) All information necessary for the routing of TA cables by the MCCS, including the number and types of cables associated with the electronics, minimum bend radius, length of cables, etc.
(d) The connection interface between TA cables and MCCS cables.
(e) The communications interface with the TA braking/caging control subsystem electronics, including parameters for monitoring, control, and annunciation.

11.2.8 Pressure Window Control Subsystem/MCCS Interface

Interface Number: TA_MCCS_08
Responsible for Documentation: U.S. Prime Contractor

11.2.8.1 Description – This interface controls the functional interfaces between the MCCS and the TA pressure window control subsystem electronics and the physical mounting interface of the electronics into the MCCS equipment racks. Also included is the interface for the associated cables that will be routed by the MCCS. The MCCS will supply and route all inter-system cables (i.e., between the MCCS, AS, TA, SSMO, or SI). All intra-system cables will be supplied by that system and will only be routed by the MCCS. Note that even though the interface is identified separately, it is acceptable for all of the TA communications interfaces with the MCCS to take place over one physical connection. This document does not require that a separate communications interface be established with the pressure window control subsystem electronics. This interface is documented in the TA_MCCS_F and the TA_MCCS_P ICDs.

11.2.8.2 Interface Contents – The following items, as a minimum, will be controlled as part of this interface and shall appear in the ICD controlling this interface:

(a) The mounting interface between the TA pressure window control subsystem electronics and the MCCS equipment racks.
(b) The mass and center of gravity (c.g.) limits of the TA pressure window control subsystem electronics.
(c) All information necessary for the routing of TA cables by the MCCS, including the number and types of cables associated with the electronics, minimum bend radius, length of cables, etc.
(d) The connection interface between TA cables and MCCS cables.
(e) The communications interface with the TA pressure window control subsystem electronics, including parameters for monitoring, control, and annunciation.

11.2.9 Rotation Isolation Control Subsystem/MCCS Interface

Interface Number: TA_MCCS_09
Responsible for Documentation: U.S. Prime Contractor

11.2.9.1 Description – This interface controls the functional interfaces between the MCCS and the TA rotational isolation control subsystem electronics and the physical mounting interface of the electronics into the MCCS equipment racks. Also included is the interface for the associated cables that will be routed by the MCCS. The MCCS will supply and route all inter-system cables (i.e., between the MCCS, AS, TA, SSMO, or SI). All intra-system cables will be supplied by that system and will only be routed by the MCCS. Note that even though the interface is identified separately, it is acceptable for all of the TA communications interfaces with the MCCS to take place over one physical connection. This document does not require that a separate communications interface be established with the rotational isolation control subsystem electronics. This interface is documented in the TA_MCCS_F and the TA_MCCS_P ICDs.

11.2.9.2 Interface Contents – The following items, as a minimum, will be controlled as part of this interface and shall appear in the ICD controlling this interface:

(a) The mounting interface between the TA rotational isolation control subsystem electronics and the MCCS equipment racks.
(b) The mass and center of gravity (c.g.) limits of the TA rotational isolation control subsystem electronics.
(c) All information necessary for the routing of TA cables by the MCCS, including the number and types of cables associated with the electronics, minimum bend radius, length of cables, etc.
(d) The connection interface between TA cables and MCCS cables.
(e) The communications interface with the TA rotational isolation control subsystem electronics, including parameters for monitoring, control, and annunciation.

11.2.10 Vibration Isolation Control Subsystem/MCCS Interface

Interface Number: TA_MCCS_10
Responsible for Documentation: U.S. Prime Contractor

11.2.10.1 Description – This interface controls the functional interfaces between the MCCS and the TA vibration isolation control subsystem electronics and the physical mounting interface of the electronics into the MCCS equipment racks. Also included is the interface for the associated cables that will be routed by the MCCS. The MCCS will supply and route all inter-system cables (i.e., between the MCCS, AS, TA, SSMO, or SI). All intra-system cables will be supplied by that system and will only be routed by the MCCS. Note that even though the interface is identified separately, it is acceptable for all of the TA communications interfaces with the MCCS to take place over one physical connection. This document does not require that a separate communications interface be established with the vibration isolation control subsystem electronics. This interface is documented in the TA_MCCS_F and the TA_MCCS_P ICDs.

11.2.10.2 Interface Contents – The following items, as a minimum, will be controlled as part of this interface and shall appear in the ICD controlling this interface:

(a) The mounting interface between the TA vibration isolation control subsystem electronics and the MCCS equipment racks.
(b) The mass and center of gravity (c.g.) limits of the TA vibration isolation control subsystem electronics.
(c) All information necessary for the routing of TA cables by the MCCS, including the number and types of cables associated with the electronics, minimum bend radius, length of cables, etc.
(d) The connection interface between TA cables and MCCS cables.
(e) The communications interface with the TA vibration isolation control subsystem electronics, including parameters for monitoring, control, and annunciation.

11.2.11 Pressure Seal/Compensator Control Subsystem/MCCS Interface

Interface Number: TA_MCCS_11
Responsible for Documentation: U.S. Prime Contractor

11.2.11.1 Description – This interface controls the functional interfaces between the MCCS and the TA pressure seal/compensator control subsystem electronics and the physical mounting interface of the electronics into the MCCS equipment racks. Also included is the interface for the associated cables that will be routed by the MCCS. The MCCS will supply and route all inter-system cables (i.e., between the MCCS, AS, TA, SSMO, or SI). All intra-system cables will be supplied by that system and will only be routed by the MCCS. Note that even though the interface is identified separately, it is acceptable for all of the TA communications interfaces with the MCCS to take place over one physical connection. This document does not require that a separate communications interface be established with the pressure seal/compensator control subsystem electronics. This interface is documented in the TA_MCCS_F and the TA_MCCS_P ICDs.

11.2.11.2 Interface Contents – The following items, as a minimum, will be controlled as part of this interface and shall appear in the ICD controlling this interface:

(a) The mounting interface between the TA pressure seal/compensator control subsystem electronics and the MCCS equipment racks.
(b) The mass and center of gravity (c.g.) limits of the TA pressure seal/compensator control subsystem electronics.
(c) All information necessary for the routing of TA cables by the MCCS, including the number and types of cables associated with the electronics, minimum bend radius, length of cables, etc.
(d) The connection interface between TA cables and MCCS cables.
(e) The communications interface with the TA pressure seal/compensator control subsystem electronics, including parameters for monitoring, control, and annunciation.

11.2.12 MCCS/Telescope Cable Distribution Interface

Interface Number: TA_MCCS_12
Responsible for Documentation: U.S. Prime Contractor

11.2.12.1 Description – This interface controls the routing of cables that are not addressed in the specific interfaces between the MCCS and each of the individual subsystems given earlier in this section. The MCCS will design the observatory electrical cable routing layout. It will supply and route all inter-system cables (i.e., between the MCCS, AS, TA, SSMO, or SI). All intra-system cables will be supplied by that system and will only be routed by the MCCS.

11.2.12.2 Interface Contents – The following items, as a minimum, will be controlled as part of this interface and shall appear in the ICD controlling this interface:

(a) All information necessary for the routing of TA cables by the MCCS, including the number and types of cables associated with the electronics, minimum bend radius, length of cables, etc.
(b) The connection interface between TA cables and MCCS cables, where necessary.
(c) The interface (if necessary) between the MCCS and the TA cable load alleviation device.

11.2.13 TA Video Subsystem/MCCS Interface

Interface Number: TA_MCCS_13
Responsible for Documentation: U.S. Prime Contractor

11.2.13.1 Description – This section refers to the interface between the video signals supplied by the TA and the MCCS. The video signals are expected to be generated by the TA imagers and the focal plane imagers.

11.2.13.2 Interface Contents – The following items, as a minimum, will be controlled as part of this interface and shall appear in the ICD controlling this interface:

(a) All information necessary for the routing of TA video cables by the MCCS, including the number and types of cables, minimum bend radius, length of cables, etc.
(b) The connection interface between TA video cables and the MCCS.
(c) The format used in the transmission of TA video signals.

11.2.14 Telescope Assembly/MCCS Blind Pointing Interface

Interface Number: TA_MCCS_14
Responsible for Documentation: U.S. Prime Contractor

11.2.14.1 Description – This interface controls the mounting on the telescope, of any equipment supplied by the MCCS for the purposes of providing a blind pointing capability. Blind pointing is the ability to initially point the telescope to a given position in the sky to within a specified accuracy. This capability will be supplied by the MCCS. To this end, there may be a need to mount gyros and/or antennas directly on the telescope.

11.2.14.2 Interface Contents – The following items, as a minimum, will be controlled as part of this interface and shall appear in the ICD controlling this interface:

(a) The mounting interface between any MCCS-supplied gyro and the Telescope Assembly.
(b) The mounting of any antennas (such as GPS) to the telescope.
(c) The routing of cables associated with the gyro or antenna.
(d) The mass limits of any mounted equipment.

11.2.15 TA/MCCS Interface

Interface Number: TA_MCCS_F
TA_MCCS_P
Lead Responsibility for Documentation: U.S. Prime Contractor

11.2.15.1 Description This interface controls functional and physical interfaces between the TA and MCCS data systems. This ICD is separated into two parts; TA_MCCS_Functional (TA_MCCS_F), and TA_MCCS_Physical (TA_MCCS_P).

11.2.15.2 Interface Contents – At a minimum, the following interfaces will be controlled as part of this ICD:

(a) SOFIA LAN architecture
(b) Primary/Tertiary Mirror Electronics Subsystem/MCCS
(c) Thermal Control Subsystem/MCCS
(d) Secondary Mirror Control Subsystem/MCCS
(e) Rotational Drive Control Subsystem/MCCS
(f) Tracking Control Subsystem/MCCS
(g) Balancing Control Subsystem/MCCS
(h) Braking/Caging Control Subsystem/MCCS
(i) Pressure Window Control Subsystem/MCCS
(j) Rotation Isolation Control Subsystem/MCCS
(k) Vibration Isolation Control Subsystem/MCCS
(l) Pressure Seal/Compensator Control Subsystem/MCCS

11.3 TELESCOPE ASSEMBLY/SOFIA SCIENCE MISSION OPERATIONS (SSMO) INTERFACES

11.3.1 SSMO GSF/Telescope Assembly Interfaces

Interface Number: TA_SSMO_01
Responsible for Documentation: U.S. Prime Contractor

11.3.1.1 Description – This section refers to the interface between the TA and the ground support facility. The purpose of this interface is for the TA to document any special requirements that are to be placed on the GSF. It is not necessary that requirements be generated for all items in the paragraph below. This interface only covers GSF requirements that are not addressed in the Facility Requirements Document (FRD) or in another interface.

11.3.1.2 Interface Contents – The following items, as a minimum, will be controlled as part of this interface and shall appear in the ICD controlling this interface:

(a) TA GSF equipment storage interface requirements. This includes a description of all TA equipment that must be stored in the GSF, including dimensions, mass, special storage requirements, and adjacency requirements. If a piece of equipment is needed on a deployment mission, then that should also be specified here.
(b) TA GSF power interface requirements. This includes any special power requirements for TA ground support equipment and locations where power is needed.
(c) TA GSF facility crane interface requirements. Requirements for the facility crane include capacity, speed control, and locations for the crane.
(d) TA GSF LN2 supply requirements. The amount of liquid nitrogen needed during operations would be specified here.
(e) TA GSF HVAC interface requirements. Any special heating and cooling requirements in the ground support facility would be included here.
(f) TA GSF LAN interface requirements. Requirements for the number and locations of connections to the GSF LAN would be included.
(g) TA GSF pneumatic interface requirements. Requirements for pneumatic capacity, and locations would be included.
(h) TA GSF lighting interface requirements. Any special requirements for lighting in the ground support facility would be specified here.
(i) TA GSF water interface requirements. If water is needed for any purpose, those requirements would be given here.
(j) TA GSF drainage interface requirements. If there is any need for drainage, those requirements would be given here.
(k) TA GSF Hazardous materials interface requirements. If the TA would need the use of any hazardous materials, those requirements would be specified here.
(l) TA GSF Additional maintenance requirements. If there are any additional maintenance requirements for the TA or ground support equipment that is not covered in previous sections, those requirements would be given here.

11.3.2 SSMO Removal and Installation GSE/TA Optical Assemblies Handling Interface

Interface Number: TA_SSMO_02
Responsible for Documentation: Telescope Assembly Contractor

11.3.2.1 Description – A set of interfaces is needed between the SSMO removal and installation ground support equipment and the TA optical assemblies. It is assumed that the actual interfaces will occur with handling fixtures that are supplied by the TA. This section refers to both the physical mounting interfaces needed in addition to the procedures necessary for the installation and removal of the optical assemblies.

11.3.2.2 Interface Contents – The following items, as a minimum, will be controlled as part of this interface and shall appear in the ICD controlling this interface:

(a) The mounting interface between the SSMO and the handling fixtures for each of TA optical assemblies.
(b) Mass and c.g. properties of each of the TA optical assemblies.

(c) The procedures used for the installation and removal of the optical assemblies from the telescope.
(d) The maximum allowable loads and accelerations applied to the optical assemblies during installation and removal.

11.3.3 SSMO Removal and Installation GSE/Telescope Subassembly Handling Interface

Interface Number: TA_SSMO_03
Responsible for Documentation: Telescope Assembly Contractor

11.3.3.1 Description – A set of interfaces is needed between the SSMO removal and installation ground support equipment and the TA subassemblies. This interface includes the installation and removal of all parts of the telescope except the optical assemblies, which are treated in a separate interface. This section refers to both the physical mounting interfaces needed in addition to the procedures necessary for the installation and removal of the telescope sub-assemblies.

11.3.3.2 Interface Contents – The following items, as a minimum, will be controlled as part of this interface and shall appear in the ICD controlling this interface:

(a) The mounting interface between the SSMO and the handling fixtures for each of TA subassemblies.
(b) Mass and c.g. properties of each of the TA subassemblies.
(c) The procedures used for the installation and removal of the telescope assembly to the aircraft cavity.
(d) The maximum allowable loads and accelerations applied to the subassemblies during installation and removal.

11.3.4 SSMO Ground Handling GSE/TA Optical Assemblies Interface

Interface Number: TA_SSMO_04
Responsible for Documentation: U.S. Prime Contractor

11.3.4.1 Description – A set of interfaces is needed between the SSMO ground handling equipment and the TA optical assemblies. It is assumed that the actual interfaces will occur with handling fixtures that are supplied by the TA. This interface is separate from TA_SSMO_02 since a different set of equipment may be needed on the ground as opposed to installation and removal.

11.3.4.2 Interface Contents – The following items, as a minimum, will be controlled as part of this interface and shall appear in the ICD controlling this interface:

(a) The mounting interface between the SSMO ground handling equipment and the handling fixtures for each of TA optical assemblies.
(b) Mass and c.g. properties of each of the TA optical assemblies.
(c) The maximum allowable loads and accelerations applied to the optical assemblies on the ground.

11.3.5 SSMO Ground Handling GSE/Telescope Subassembly Handling Interface

Interface Number: TA_SSMO_05
Responsible for Documentation: U.S. Prime Contractor

11.3.5.1 Description – A set of interfaces is needed between the SSMO ground handling equipment and each of the TA subassemblies. It is assumed that the actual interfaces will occur with handling fixtures that are supplied by the TA.

11.3.5.2 Interface Contents – The following items, as a minimum, will be controlled as part of this interface and shall appear in the ICD controlling this interface:

(a) The mounting interface between the SSMO ground handling equipment and the handling fixtures for each of TA subassemblies.
(b) Mass and c.g. properties of each of the TA subassemblies.
(c) The maximum allowable loads and accelerations applied to the subassemblies on the ground.

11.3.6 SSMO Mirror Processing Facility/TA Optical Assemblies Interface

Interface Number: TA_SSMO_06
Responsible for Documentation: U.S. Prime Contractor

11.3.6.1 Description – This section refers to the interface between the TA optical assemblies and the SSMO mirror processing facility. The interface includes mounting of the optical assemblies in the mirror stripping/cleaning facility and the mirror coating facility. The interface will also contain the processes involved in stripping, cleaning, and recoating the mirrors.

11.3.6.2 Interface Contents – The following items, as a minimum, will be controlled as part of this interface and shall appear in the ICD controlling this interface:

(a) Mounting interface between TA optics and the SSMO Mirror Processing Facility.
(b) Processes used for stripping, cleaning, and re-coating optical elements, including chemicals used.
(c) Spatial envelope available to TA optics.
(d) Environments inside the Mirror Processing Facility.
(e) Interface for cleaning of optics while still installed on the TA.

11.3.7 Telescope Spider Assembly/SSMO Provided Spider Covers Mount Interface

Interface Number: TA_SSMO_07
Responsible for Documentation: U.S. Prime Contractor

11.3.7.1 Description – The spider covers are used to reduce the amount of stray light on the telescope. The covers are provided by the SSMO and must attach to the bottom of the spiders. This interface controls the mounting of the spider covers to the spiders.

11.3.7.2 Interface Contents – The following items, as a minimum, will be controlled as part of this interface and shall appear in the ICD controlling this interface:

(a) The mounting interface between the SSMO spider covers and the TA spiders
(b) Mass and c.g. properties of the spider covers.

11.3.8 Telescope Assembly/Baffle Plate Mount Interface

Interface Number: TA_SSMO_08
Responsible for Documentation: U.S. Prime Contractor

11.3.8.1 Description – The baffle plate is located behind the tertiary mirror as viewed from the focal plane. The purpose of defining an interface is to allow for the SSMO to supply additional baffle configurations to mount to the telescope.

11.3.8.2 Interface Contents – The following items, as a minimum, will be controlled as part of this interface and shall appear in the ICD controlling this interface:

(a) The mounting interface between the SSMO baffles and the TA baffle plate
(b) Mass and c.g. properties of the SSMO baffles.

11.3.9 Telescope Secondary Mirror/SSMO Provided Secondary Mirror Button Mount Interface

Interface Number: TA_SSMO_09
Responsible for Documentation: U.S. Prime Contractor

11.3.9.1 Description – The SSMO will provide a button in the middle of the secondary mirror to prevent the focal plane from generating an image of itself in the middle of the secondary mirror. This interface controls the mounting of the button to the secondary mirror.

11.3.9.2 Interface Contents – The following items, as a minimum, will be controlled as part of this interface and shall appear in the ICD controlling this interface:

(a) The mounting interface between the SSMO button and the TA secondary mirror.
(b) Mass and c.g. properties of the SSMO secondary mirror button.

11.3.10 TA Primary Mirror/SSMO Sun Filter Interface

Interface Number: TA_SSMO_10
Responsible for Documentation: Telescope Assembly Contractor

11.3.10.1 Description – A full aperture sun filter will be used for solar viewing. An interface is required with the telescope in order to mount this vignetting stop.

11.3.10.2 Interface Contents – The following items, as a minimum, will be controlled as part of this interface and shall appear in the ICD controlling this interface:

(a) The mounting interface between the SSMO sun filter and the TA.
(b) Mass size and c.g. properties of the sun filter.

11.3.11 TA Flange/SSMO GSE Telescope Flange Mockup Interface

Interface Number: TA_SSMO_11
Responsible for Documentation: Telescope Assembly Contractor

11.3.11.1 Description – The SSMO will provide a telescope flange mockup in the ground support facility. This interface will not drive the design of the telescope instrument flange. However, it is necessary for the definition of the flange interface to the science instrument to be set at some point for the development of the SSMO-provided mockup to proceed.

11.3.11.2 Interface Contents – The following items, as a minimum, will be controlled as part of this interface and shall appear in the ICD controlling this interface:

(a) The mounting interface between the TA SI mounting flange and the SI.

11.3.12 SSMO-Supplied Secondary Mirror/Telescope Interface

Interface Number: TA_SSMO_12
Responsible for Documentation: Telescope Assembly Contractor

11.3.12.1 Description – At some point the SSMO may provide an additional secondary mirror. The purpose of this interface is to document the mounting interface between the secondary mirror and the secondary mirror assembly.

11.3.12.2 Interface Contents – The following items, as a minimum, will be controlled as part of this interface and shall appear in the ICD controlling this interface:

(a) The mounting interface between the secondary mirror and the secondary mirror assembly.
(b) Dynamic characteristics of the secondary mirror assembly.
(c) Static weight envelope for the secondary mirror.
(d) Optical prescription of the secondary mirror.

11.3.13 SSMO-Supplied Tertiary Mirror/Telescope Interface

Interface Number: TA_SSMO_13
Responsible for Documentation: Telescope Assembly Contractor

11.3.13.1 Description – At some point the SSMO may provide an additional tertiary mirror. The purpose of this interface is to document the mounting interface between the tertiary mirror and the tertiary mirror assembly.

11.3.13.2 Interface Contents – The following items, as a minimum, will be controlled as part of this interface and shall appear in the ICD controlling this interface:

(a) The mounting interface between the tertiary mirror and the tertiary mirror assembly.
(b) Static weight envelope for the tertiary mirror.
(c) Optical prescription and characteristics of the tertiary mirror.

11.4 TELESCOPE ASSEMBLY/SCIENCE INSTRUMENT INTERFACES

11.4.1 Telescope Assembly Cable Load Alleviation Device/Science Instrument Cable Interface

Interface Number: TA_SI_01
Responsible for Documentation: Telescope Assembly Contractor

11.4.1.1 Description – There will be a set of cables associated with the SI that the TA will need to route through the cable load alleviation device. This interface will control the type and number of these cables.

11.4.1.2 Interface Contents – The following items, as a minimum, will be controlled as part of this interface and shall appear in the ICD controlling this interface:

(a) The type and number of SI cables and vacuum hoses routed through the TA cable load alleviation device.
(b) The properties of the cables being routed, including mass, stiffness, size, minimum bend radius, etc.

11.4.2 Telescope Assembly/Science Instrument Mounting Interface

Interface Number: TA_SI_02
Responsible for Documentation: Telescope Assembly Contractor

11.4.2.1 Description – This interface controls the mounting of the science instrument to the telescope instrument flange. In addition to the mounting of the SI, this interface includes connections between the SI and the pressure coupler and the exhaust tube.

11.4.2.2 Interface Contents – The following items, as a minimum, will be controlled as part of this interface and shall appear in the ICD controlling this interface:

(a) The mounting interface between the SI and the telescope instrument flange.
(b) Mass and c.g. properties of the SI.
(c) The interface for the pressure coupler. This interface is created to allow the SI to connect to the low pressure air of the cavity.
(d) The interface to the exhaust tube. The exhaust tube will connect the SI to the aircraft fuselage to allow airflow through the instrument and Nasmyth tube.
(e) The interface with the vacuum line(s).
(f) Heat dissipation requirements and interface temperature limits.
(g) Worst case loading imparted to the SI by the TA (acceleration and vibration).

11.4.3 TA Attitude Control/Principal Investigator Computer Direct Digital Interface

Interface Number: TA_SI_03
Responsible for Documentation: Telescope Assembly Contractor

11.4.3.1 Description – Most communication between the TA and the SI will occur via the MCCS. However, there will be a need for the SI computer to command the TA directly (via an appropriate summing junction such as may be found within a track loop processor). This interface covers the communications interfaces between the TA

tracker processor and the PI computer. The physical connection will be provided via a MCCS patch panel.

11.4.3.2 Interface Contents – The following items, as a minimum, will be controlled as part of this interface and shall appear in the ICD controlling this interface:

(a) Definition of the communication parameters exchanged between the PI computer and the TA tracker processor.
(b) The communications protocols used.

11.4.4 TA Chopper Processor/Principal Investigator Computer Direct Analog Interface

Interface Number: TA_SI_04
Responsible for Documentation: Telescope Assembly Contractor

11.4.4.1 Description – The TA chopper must provide a method to allow control of the chopper and the direct input of an analog chopper waveform from the PI computer. The physical connection will be provided via an MCCS patch panel.

11.4.4.2 Interface Contents – The following items, as a minimum, will be controlled as part of this interface and shall appear in the ICD controlling this interface:

(a) Definition of the communication parameters exchanged between the PI computer and the TA chopper processor.
(b) The communications protocols used.
(c) The signal voltage levels, timing relationships, etc.

11.5 AIRCRAFT SYSTEM/SCIENCE INSTRUMENT INTERFACES

No Aircraft System to Science Instrument interfaces have been identified.

11.6 MCCS/SCIENCE INSTRUMENT INTERFACES

11.6.1 Principal Investigator Equipment Rack/PI Equipment Mounting Interface

Interface Number: MCCS_SI_01
Responsible for Documentation: U.S. Prime Contractor

11.6.1.1 Description – This interface controls the mounting interface of the Principal Investigator's equipment and computers into the MCCS equipment racks. Also included is the interface for the associated cables that will be routed by the MCCS. The MCCS will supply and route all inter-system cables (i.e., between the MCCS, AS, TA, SSMO, or SI). All intra-system cables will be supplied by that system and will only be routed by the MCCS.

11.6.1.2 Interface Contents – The following items, as a minimum, will be controlled as part of this interface and shall appear in the ICD controlling this interface:

(a) The mounting interface between the PI equipment and the MCCS equipment racks.
(b) The mass and center of gravity (c.g.) limits of the PI equipment.
(c) Heat dissipation limits of all equipment mounted in the MCCS racks.

(d) All information necessary for the routing of PI equipment cables by the MCCS, including the number and types of cables associated with the equipment, minimum bend radius, length of cables, etc.
(e) The connection interface between SI cables and MCCS cables.
(f) The power interface, including the type and quantity, and power cable connection interfaces.

11.6.2 Principal Investigator Computer/MCCS Interface

Interface Number: MCCS_SI_02
Responsible for Documentation: U.S. Prime Contractor

11.6.2.1 Description – This interface controls the functional interfaces between the MCCS and the Principal Investigator's computer.

11.6.2.2 Interface Contents – The following items, as a minimum, will be controlled as part of this interface and shall appear in the ICD controlling this interface:

(a) The communications interface with the PI computer, including parameters for monitoring, control, and annunciation.
(b) The type, format, and other necessary specifications of video signals that will be used.
(c) The amount of 60 Hz converter and UPS power available at the patch panel.

11.6.3 MCCS Patch Panel/SI Cable Interface

Interface Number: MCCS_SI_03
Responsible for Documentation: U.S. Prime Contractor

11.6.3.1 Description – The MCCS will provide a patch panel for use by the PI. The patch panel will provide connections to the facility LAN and analog connections to the TA chopper. The PI can use the patch panel to supply an analog signal to the TA chopper controller.

11.6.3.2 Interface Contents – The following items, as a minimum, will be controlled as part of this interface and shall appear in the ICD controlling this interface:

(a) A description of all the signal/network interfaces provided by the patch panel.
(b) Connection interfaces for each of the signals provided at the patch panel.
(c) Location of the patch panel.

11.7 SOFIA SCIENCE AND MISSION OPERATIONS/SCIENCE INSTRUMENT INTERFACES

11.7.1 SSMO GSF/SI Requirements

Interface Number: SSMO_SI_01
Responsible for Documentation: U.S. Prime Contractor

11.7.1.1 Description – This section refers to the interface between the SI and the ground support facility. The purpose of this interface is for the SI to document any special

requirements that are to be placed on the GSF. It is not necessary that requirements be generated for all items in the paragraph below. This interface only covers GSF requirements that are not addressed in the Facility Requirements Document (FRD) or in another interface.

11.7.1.2 Interface Contents – The following items, as a minimum, will be controlled as part of this interface and shall appear in the ICD controlling this interface:

(a) SI GSF equipment storage interface requirements. This includes a description of all SI equipment that must be stored in the GSF, including dimensions, mass, special storage requirements, and adjacency requirements. If a piece of equipment is needed on a deployment mission, then that should also be specified here.
(b) SI GSF power interface requirements. This includes any special power requirements for SI ground support equipment and locations where power is needed.
(c) SI GSF facility crane interface requirements. Requirements for the facility crane include capacity, speed control, and locations for the crane.
(d) SI GSF LN2 supply requirements. The amount of liquid nitrogen needed during operations would be specified here.
(e) SI GSF HVAC interface requirements. Any special heating and cooling requirements in the ground support facility would be included here.
(f) SI GSF LAN interface requirements. Requirements for the number and locations of connections to the GSF LAN would be included.
(g) SI GSF pneumatic interface requirements. Requirements for pneumatic capacity, and locations would be included.
(h) SI GSF lighting interface requirements. Any special requirements for lighting in the ground support facility would be specified here.
(i) SI GSF water interface requirements. If water is needed for any purpose, those requirements would be given here.
(j) SI GSF drainage interface requirements. If there is any need for drainage, those requirements would be given here.
(k) SI GSF Hazardous materials interface requirements. If the SI would need the use of any hazardous materials, those requirements would be specified here.
(l) SI GSF Additional maintenance requirements. If there are any additional maintenance requirements for the SI or ground support equipment that is not covered in previous sections, those requirements would be given here.

11.7.2 SSMO TA Ground Simulator/Science Instrument Mount Interface

Interface Number: SSMO_SI_02
Responsible for Documentation: U.S. Prime Contractor

11.7.2.1 Description – This section controls the interface between the SI and the SSMO TA ground simulator. The mounting interface for the instrument will be identical to the actual interface on the telescope. The interface between the SI and the TA ground simulator is treated separately to ensure that the flange is identical to the flight article.

11.7.2.2 Interface Contents – The following items, as a minimum, will be controlled as part of this interface and shall appear in the ICD controlling this interface:

(a) The mounting interface between the SI and the telescope instrument flange.
(b) Mass and c.g. properties of the SI.
(c) The interface for the pressure coupler. This interface is created to allow the SI to connect to the low pressure air of the cavity.

11.7.3 SSMO Cryogenic Supply/SI Interface

Interface Number: SSMO_SI_03
Responsible for Documentation: U.S. Prime Contractor

11.7.3.1 Description – The SSMO is responsible for providing a cryogenic supply for use by the PI during operation. The cryogenic supply may be either a portable dewar, or a built-in dewar with a supply line that connects to the SI.

11.7.3.2 Interface Contents – The following items, as a minimum, will be controlled as part of this interface and shall appear in the ICD controlling this interface:

(a) The required capacity of the cryogenic supply.
(b) The type of connection for transfer of the cryogen.
(c) The spatial envelope required for transfer of the cryogen.
(d) The location and type of light sources used for alignment of the SI.