ESC-TR-2010-070

Project Report
HUSIR-7

Interface Control Document between the Radio Astronomy Pointing Computer (PC) and the HUSIR Antenna Control Unit (ACU)

J.V. Eshbaugh

7 December 2010

Lincoln Laboratory
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LEXINGTON, MASSACHUSETTS

Prepared for the Department of the Air Force under Contract FA8721-05-C-0002.

This report is based on studies performed at Lincoln Laboratory, a center for research operated by Massachusetts Institute of Technology. This work was sponsored by the Department of the Air Force, 850 ELSG/NS, under Contract FA8721-05-C-0002.

Massachusetts Institute of Technology
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1. INTRODUCTION AND SCOPE

The Antenna Control Unit (ACU) is required to communicate with the Haystack Radar and Astronomy Pointing Computers (PC). This document defines the physical and logical interfaces the ACU will use to communicate with the Pointing Computers.

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2. RELATED DOCUMENTS AND DRAWINGS

HUSIR Antenna Control System Requirements Document

HUSIR Antenna Control System Design Document

HUSIR pointing computer switch drawing #TBD

HUSIR Antenna Control Security Plan

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3. PHYSICAL INTERFACE CHARACTERISTICS

3.1 MECHANICAL

The physical interface shall be 100BaseT Ethernet over copper twisted-pair wiring in accordance with IEEE 802.3-2002. There shall be a security approved switching mechanism between the pointing computer (radar or astronomy) and the ACU.

3.2 ELECTRICAL

The data format shall be UDP/IP in accordance with RFC 768, 894, and associated documents. The address and port number shall be configurable at run time with the restriction that the port number shall be 1024 or greater. The nominal port for connection to the ACU shall be port 4003. The PC shall be responsible for connecting to the ACU.

During normal operation the active Pointing Computer (PC) and ACU shall exchange command and status messages at a nominal rate of 100 Hz. The communications between the PC and ACU is asynchronous. The ACU shall send unsolicited status messages at the 100 Hz rate to the PC upon connection.

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4. SOFTWARE AND NETWORK

4.1 DATA TYPES

All messages shall utilize the data types shown in Table 1. All data fields shall be aligned as specified. Reserved fields shall be included as necessary to obtain the required alignments. Byte order shall be network byte order (big-endian). The rightmost bit of a word shall be designated bit 0 and shall be the least significant bit.

Table 1 – Allowable Data Types

Type	Alignment	Description
char	1	ASCII character
int8	1	8-bit signed integer (2's complement)
uint8	1	8-bit unsigned integer
int16	2	16-bit signed integer (2's complement)
uint16	2	16-bit unsigned integer
int32	4	32-bit signed integer (2's complement)
uint32	4	32-bit unsigned integer
float	4	32-bit IEEE-754 floating point
double	8	64-bit IEEE-754 floating point

4.2 UNITS

All message types requiring units shall be specified in accordance with the International System of Units (SI MKS system). Temperatures shall be in degrees Celsius. Times of Validity (TOV) shall be in seconds after midnight GMT. Angles shall be in radians.

4.3 MESSAGE FORMAT

All messages include a header that contains a message type identifier, a status request flag, and a counter to detect lost messages. The definition of the message header is shown in Table 2.

Table 2 – Message Header Definition

Type	Name	Description
uint8	Id	Message type identifier
unt8	request_id	Request status of the given type
unt8	acs_count	Message counter for PC to ACU
unt8	acu_count	Message counter for ACU to PC

If the request_id field is not zero, and it is a valid status message identifier, the ACU shall respond with a status message of the requested type. The purpose of this mechanism is to allow the PC to request various status messages while only sending the 100 Hz Pointing Message through the outbound security guard.

Since the physical layer is known to be Ethernet it is not necessary to include a message length or checksum, as the link layer will discard damaged packets. The message counters can be used to detect lost packets.

4.4 MESSAGE TYPES

Message types are divided into pointing and non-pointing messages. The pointing messages shall be sent at the 100 Hz rate and do not require any response. Non-pointing messages shall be sent on demand and require an acknowledge response.

4.4.1 Pointing Messages

The pointing messages supported by the ACU are shown in Table 3. Direction is with respect to the ACU.

Table 3 – Pointing Messages

Message	Direction	Description	Message ID	Paragraph
Pointing Command	IN	Az/El Pointing Vectors	0×01	4.5.1
Pointing Status	OUT	Az/El Current Position Vectors	0×81	4.5.2

All pointing messages shall be time-tagged with a Time Of Validity (TOV). The TOV shall be a floating point value representing the number of seconds since midnight GMT.

Pointing Command messages shall have a TOV tag that refers to the future time when the antenna should have arrived at the commanded position and velocity. Pointing status messages shall have a TOV that refers to the time the data was read from the hardware. Pointing messages occur at a 100 Hz rate with no synchronization to each other. Neither the Pointing Command nor the Pointing Status message require a response or acknowledgment.

4.4.2 Non-Pointing Messages

The non-pointing messages supported by the ACU are shown in Table 4. Direction is with respect to the ACU.

Table 4 – Non-Pointing Messages

Message	Direction	Description	Message ID	Paragraph
Sub-reflector Command	IN	Sub-reflector position command	0×02	4.5.4
Sub-reflector Status	OUT	Sub-reflector position status	0×82	4.5.5
Request ACK	OUT	Message receipt acknowledged	0×80	4.5.7
Status Request	IN	Request data from ACU	0×03	4.5.8
Summary Status	OUT	ACU summary status flags	0×93	4.5.6

Non-Pointing messages sent by the ACU to the ACS require no response or acknowledgment. Non-Pointing messages sent by the PC to the ACU require a response from the ACU as shown in Table 5. The PC may send a non-pointing message to the ACU at any time. The ACU may delay responses to such messages until after the next pointing status message, or for up to 10 ms, whichever is less.

Table 5 – ACU Responses to PC Non-Pointing Messages

Message	Expected Response
Sub-reflector Command	Request ACK
System Command	Request ACK
Status Request	Requested Status (System, Sub-reflector, etc)

4.5 MESSAGE DEFINITIONS

4.5.1 Pointing Command

The PC shall send pointing command messages to the ACU at a rate of 100 Hz. This message controls the antenna operating mode, pointing angles, and sub-reflector positioning. It can also be used to request a status response from the ACU by setting the request_id field in the message header. The pointing command message is sent only by the PC, never by the ACU. The format of this message is shown in Table 6.

Table 6 – Pointing Command Message

Type	Name	Description
	header	Message header (see Table 2)
uint8	ped_mode	Pedestal mode
uint8	sub_mode	Sub-reflector mode
uint8	comp_type	Compensator type
uint8	spare	
double	tom	Time this message was sent
double	sv_tov	State vector Time of Validity
double	az	Unambiguous azimuth, CW from true North (radians)
double	az_rate	Azimuth rate (radians/sec)
double	az_accel	Azimuth acceleration (rad/sec^2)
double	el	Elevation, increasing above horizon (radians)
double	el_rate	Elevation rate (radians/sec)
double	el_accel	Elevation acceleration (rad/sec^2)
double	sub_x	Sub-reflector X offset (meters)
double	sub_y	Sub-reflector Y offset (meters)
double	sub_z	Sub-reflector Z offset (meters)
double	sub_ang_x	Sub-reflector angle offset about X (radians)
double	sub_ang_y	Sub-reflector angle offset about Y (radians)

4.5.1.1 Pedestal Mode

The allowed values for the ped_mode field are as shown in Table 7.

Table 7 – Allowable Pedestal Modes

Mode	Value	Description
STANDBY	0	Stop motion, enable brakes, disable amplifiers
SLEW	1	Move at constant velocity
POINT	2	Point to designated angles (normal operation)
STOW1	3	Move to stow position #1 and stop.
STOW2	4	Move to stow position #2 and stop
STOW3	5	Move to stow position #3 and stop
TEST	6	Maintenance computer GUI is commanding a test excitation.

4.5.1.2 Sub-reflector Mode

The allowed values are IGNORE, AUTO, MANUAL, and LOCK as shown in Table 8. The IGNORE mode shall indieate that the pointing eommand is not being used to position the sub-refleetor. This is intended to allow the sub-refleetor to be eontrolled via the sub-refleetor eommand.

The AUTO mode shall indieate that the sub-refleetor will be positioned automatieally by the ACU based on the mount model. In this mode the sub-refleetor position will be interpreted as an offset from the eomputed position.

The MANUAL mode shall eause the sub-refleetor position to be interpreted as an absolute position value. The mount model will be ignored.

The LOCK mode shall eause the sub-refleetor to stay where it is eurrently positioned. All position sourees, both internal and external, will be ignored. The intent of this mode is to allow the PC to lock the sub-refleetor position for the duration of a measurement.

Table 8 – Allowable Sub-reflector Modes

Mode	Value	Description
IGNORE	0	Ignore sub-reflector portion of message
AUTO	1	Position is offset from mount model position
MANUAL	2	Position is absolute position, ignore mount model
LOCK	3	Ignore all sub-reflector positioning commands

4.5.1.3 Compensator Type

The eompensator type byte seleets between Type I and Type II servo eompensators when the ACU is using the eonventional eompensator. It is ignored when the ACU is using the MIMO eompensator. The allowed values for the eompensator type are shown in Table 9.

Table 9 – Allowable Compensator Type Values

Mode	Value	Description
AUTO	0	Automatically select compensator type
TYPE_1	1	Force Type I
TYPE_2	2	Force Type II

4.5.1.4 Azimuth and Elevation

The azimuth and elevation position shall be expressed in radians. The range of the unambiguous azimuth shall be -2π to $+2\pi$. The range of the ambiguous azimuth shall be 0 to 2π. The range of the elevation shall be 0 to π.

Azimuth and elevation rates shall be expressed in radians/sec. The range of the azimuth rate shall be $-5\pi/180$ to $+5\pi/180$. The range of the elevation rate shall be $-2\pi/180$ to $+2\pi/180$.

Azimuth and elevation accelerations shall be expressed in radians/sec^2. The range of the azimuth and elevation accelerations shall be $-2\pi/180$ to $+2\pi/180$.

4.5.1.5 Sub-reflector Position

When looking toward the sub-reflector from the focus, with the main reflector pointed to zero elevation, the positive Z direction shall be away from the main reflector, positive Y shall be up, and positive X shall be to the left. The direction of positive rotation about an axis shall be defined by the right-hand rule (i.e., positive is counter-clockwise when looking toward the origin).

The sub-reflector X, Y, and Z position shall be expressed in meters. The range for each of these shall be -100 to $+100\times10^{-3}$ (range of 200 mm). The X and Y angles shall be expressed in radians, with a range of -70×10^{-3} to $+70\times10^{-3}$ (-0.016 to +0.016 degrees). Note that these limits are the largest possible when each axis is moved individually. The actual angle ranges will vary depending on the sub-reflector linear position, and vice versa.

4.5.2 Pointing Status

The ACU shall send pointing status messages to the Pointing Computer at a rate of 100 Hz. This message contains a summary status of the pedestal, including the current operating mode, pointing angles, and sub-reflector position. The Pointing Status shall be the only message the ACU sends unsolicited. The pointing status message is defined in Table 10.

Table 10 – Pointing Status Message

Type	Name	Description
	header	Message header (See Table 2)
uint8	ped_mode	Pedestal mode
uint8	sub_mode	Sub-reflector mode
uint8	pending	Pending command bits
uint8	spare	
double	tom	Time this message was sent
double	sv_tov	State vector Time of Validity
double	az	Unambiguous azimuth, CW from true North (radians)
double	az_rate	Azimuth rate (radians/sec)
double	az_accel	Azimuth acceleration (rad/sec^2)
double	el	Elevation, increasing above horizontal (radians)
double	el_rate	Elevation rate (radians/sec)
double	el_accel	Elevation acceleration (rad/sec^2)
double	az_raw	Unambiguous azimuth without mount model
double	az_ambig	Azimuth position normalized to [0,2PI)
double	el_raw	Elevation position without mount model
uint32	ilock_status	Interlock status summary bits
uint32	drive_status	AZ/EL drive status bits
uint32	limit_status	Limit status bits
uint32	az_counts	Raw azimuth encoder and sector switches
uint32	el_counts_1	Raw elevation encoder #1 counts
uint32	el_counts_2	Raw elevation encoder #2 counts

4.5.2.1 Pending Command Bits

The pending and fail bits indicate the current status of mode changes for both the pedestal and the hexapod. Bits 0–1 represent the status of mode changes to be applied to the pedestal and Bits 2–3 represent the status of mode changes to be applied to the hexapod as shown in Table 11. If the pending bit is set, then there is a mode change in progress. If the fail bit is set, then the last mode change failed. The fail bit is only guaranteed to be valid when the pending bit is clear. The relationship of these bits is shown in Table 12.

Table 11 – Pending Command Bits Definition

Bit	Name	Description
0	mode_change	Pedestal mode change is pending
1	mode_fail	Last pedestal mode change failed
2	sub_change	Hexapod mode change is pending
3	sub_fail	Last hexapod mode change failed
4	Local_mode	ACU in local mode
5:7	spare	

Table 12 – Relationship of Change and Fail Bits

Change Bit	Fail Bit	Meaning
0	0	No change pending, no failures
1	0	Change pending, no failures
0	1	No change pending, last one failed
1	1	Change pending, last one failed

4.5.3 Pedestal and Sub-reflector Mode Bytes

The pedestal and sub-reflector mode bytes shall be interpreted the same way that they are for the pointing command and documented in Table 7 and Table 8, respectively. The status shall indicate the actual ACU mode, which may not be the same as the last commanded mode due to processing delays.

4.5.3.1 Interlock Status Summary

For all interlocks, regardless of their actual polarity, a high (1) bit in the status summary indicates a system fault condition which will cause the ACU to disable the drives (i.e. an interlock condition). Bit 0 is the logical OR of the other interlock fault bits. The meaning of each bit is defined in Table 13.

Table 13 – Interlock Status Bits

Bit	Name	Description
0	fault	Logical OR of all other interlocks
1:3	reserved	
4	az_cw_final	Azimuth clockwise final limit
5	az_ccw_final	Azimuth counter-clockwise final limit
6	el_up_final	Elevation up final limit
7	el_dn_final	Elevation down final limit
8	time_code	Time code input failure
9	remote_concentrator	Remote concentrator failure
10	lcl_concentrator	Local concentrator off
11	sercans_rst	SERCANS interface being reset
12	sercans_0	SERCANS Phase 0
13	sercans_2	SERCANS Phase 2
14	sercans_4	SERCANS Phase 4
15	sercans_down	SERCANS ring down
16	az_enc_data	Azimuth encoder not responding
17	az_enc_CRC	Azimuth encoder CRC error
18	el1_enc_data	Elevation Encoder #1 Not Responding
19	el1_enc_CRC	Elevation Encoder #1 CRC error
20	el2_enc_data	Elevation Encoder #2 Not Responding
21	el2_enc_CRC	Elevation Encoder #2 CRC error
22	az_plc_ilock	Azimuth axis PLC interlock
23	el_plc_ilock	Elevation axis PLC interlock
24	az_bearing	Azimuth bearing fault
25	estop	Emergency stop pressed or key removed
26	plc_heartbeat	PLC heartbeat not present
27	az_axis_not_rdy	Azimuth axis not ready
28	el_axis_not_rdy	Elevation axis not ready
29	az_speed_fault	Speed mismatch between azimuth motors
30	el_speed_fault	Speed mismatch between elevation motors
31	Reserved	

4.5.3.2 Drive Status

For all status bits, a high (1) indicates a fault condition. Bit 0 is the logical OR of the elevation fault bits, bit 1 is the logical OR of the azimuth fault bits, and bit 2 is the logical OR of the sub-reflector actuator fault bits. The definition of each drive status bit is shown in Table 14.

Table 14 – Drive Status Bits

Bit	Name	Description
0	el_fault	Elevation drive fault
1	az_fault	Azimuth drive fault
2	actuator_fault	Sub-reflector actuator fault
3	spare	
4:7	reserved	
8	el_drive_1	Elevation amplifier #1 fault
9	el_drive_2	Elevation amplifier #2 fault
10	el_drive_3	Elevation amplifier #3 fault
11	el_drive_4	Elevation amplifier #4 fault
12:15	reserved	
16	az_drive_1	Azimuth amplifier #1 fault
17	az_drive_2	Azimuth amplifier #2 fault
18	az_drive_3	Azimuth amplifier #3 fault
19	az_drive_4	Azimuth amplifier #4 fault
20	az_drive_5	Azimuth amplifier #5 fault
21	az_drive_6	Azimuth amplifier #6 fault
22	az_drive_7	Azimuth amplifier #7 fault
23	az_drive_8	Azimuth amplifier #8 fault
24	actuator_1	Actuator #1 fault
25	actuator_2	Actuator #2 fault
26	actuator_3	Actuator #3 fault
27	actuator_4	Actuator #4 fault
28	actuator_5	Actuator #5 fault
29	actuator_6	Actuator #6 fault
30:31	spare	

4.5.3.3 Limit Status

For all limit and warning bits, a high (1) indicatcs a fault condition. Bit 0 is the logical OR of the limit bits, but 1 is the logical OR of the warning bits. The Limit Status bits are defined in Table 15.

Table 15 – Limit Status Bits

Bit	Name	Description
0	limit_hit	One or more limits hit
1	warn_hit	One or more warnings hit
2:3	spare	
4	az_cw_warn	Azimuth CW warning hit (SW limit)_
5	az_ccw_warn	Azimuth CCW warning hit (SW limit)
6	az_cw_limit	Azimuth CW limit hit (HW prelimit)
7	az_ccw_limit	Azimuth CCW limit hit (HW prelimit)
8	el_up_warn	Elevation UP warning hit (SW limit)
9	el_dn_warn	Elevation DN warning hit (SW limit)
10	el_up_lmiit	Elevation UP limit hit (HW prelimit)
11	el_dn_limit	Elevation DN limit hit (HW prelimit)
12:31	spare	

4.5.4 Sub-reflector Command

This message may be used by the PC to position the sub-reflcctor. The interprctation of the fields depends on the sub-reflector mode. In AUTO mode the sub-reflector position fields are interpreted as offsets from the position computed by the mount model. In MANUAL mode thcy are treated as absolute positions. In LOCK mode they are ignored. The fields of the Sub-reflector Command are defined in Table 16.

Table 16 – Sub-reflector Command Definition

Type	Name	Description
	header	Message header
uint8	mode	Sub-reflector positioning mode
uint8	spare	
uint8	spare	
uint8	spare	
double	sub_x	Sub-reflector X distance (meters)
double	sub_y	Sub-reflector Y distance (meters)
double	sub_z	Sub-reflector Z distance (meters)
double	sub_ang_x	Sub-reflector angle about X (radians)
double	sub_ang_y	Sub-reflector angle about Y (radians)

4.5.5 Sub-reflector Status

This message provides an overall summary status of the sub Table-reflector. Motor temperatures and currents are provided as well as status bits for critical items. The fields of the Sub-reflector Status Message are shown in Table 17.

Table 17 – Sub-reflector Status Message Definition

Type	Name	Description
	header	Message header
uint8	mode	Sub-reflector positioning mode
uint8	actuator_sts	Actuator fault bits
uint16	actuator_limit	Actuator limit bits
double	sub_x	Commanded sub-reflector X distance (meters)
double	sub_y	Commanded sub-reflector Y distance (meters)
double	sub_z	Commanded sub-reflector Z distance (meters)
double	sub_ang_x	Commanded sub-reflector angle about X (radians)
double	sub_ang_y	Commanded sub-reflector angle about Y (radians)
double	mount_x	Mount model computed X distance (meters)
double	mount_y	Mount model computed Y distance (meters)
double	mount_z	Mount model computed Z distance (meters)
double	mount_ang_x	Mount model computed angle about X (radians)
double	mount_ang_y	Mount model computed angle about Y (radians)
double	temp_1	Actuator #1 temperature (degrees C)
double	temp_2	Actuator #2 temperature (degrees C)
double	temp_3	Actuator #3 temperature (degrees C)
double	temp_4	Actuator #4 temperature (degrees C)
double	temp_5	Actuator #5 temperature (degrees C)
double	temp_6	Actuator #6 temperature (degrees C)
double	amps_1	Actuator #1 current (Amps)
double	amps_2	Actuator #2 current (Amps)
double	amps_3	Actuator #3 current (Amps)
double	amps_4	Actuator #4 current (Amps)
double	amps_5	Actuator #5 current (Amps)
double	amps_6	Actuator #6 current (Amps)

The Actuator Fault bits are defined in Table 18.

Table 18 – Actuator Fault Bits

Bit	Description
0	Summary (XOR of all other bits)
1	Reserved
2	Actuator #6
3	Actuator #5
4	Actuator #4
5	Actuator #3
6	Actuator #2
7	Actuator #1

The Actuator Limit bits are defined in Table 19.

Table 19 - Actuator Limit Bits

Bit	Description
0:1	Reserved
2	Actuator #6 Long Limit
3	Actuator #5 Long Limit
4	Actuator #4 Long Limit
5	Actuator #3 Long Limit
6	Actuator #2 Long Limit
7	Actuator #1 Long Limit
8:9	Reserved
10	Actuator #6 Short Limit
11	Actuator #5 Short Limit
12	Actuator #4 Short Limit
13	Actuator #3 Short Limit
14	Actuator #2 Short Limit
15	Actuator #1 Short Limit

4.5.6 Summary Status

This message provides an overall summary status of the pedestal health. Motor temperatures and currents are provided as well as status bits for critical items as shown in Table 20.

Table 20 – Motor Status Bit Definition

Type	Name	Description
	header	Message header
uint32	drive_status	AZ/EL drive status bits
float	temp_1	Amplifier 1 temperature (degrees C)
float	temp_2	Amplifier 2 temperature (degrees C)
float	temp_3	Amplifier 3 temperature (degrees C)
float	temp_4	Amplifier 4 temperature (degrees C)
float	temp_5	Amplifier 5 temperature (degrees C)
float	temp_6	Amplifier 6 temperature (degrees C)
float	temp_7	Amplifier 7 temperature (degrees C)
float	temp_8	Amplifier 8 temperature (degrees C)
float	temp_9	Amplifier 9 temperature (degrees C)
float	temp_10	Amplifier 10 temperature (degrees C)
float	temp_11	Amplifier 11 temperature (degrees C)
float	temp_12	Amplifier 12 temperature (degrees C)
float	amps_1	Motor 1 torque (Newton Meters)
float	amps_2	Motor 2 torque (Newton Meters)
float	amps_3	Motor 3 torque (Newton Meters)
float	amps_4	Motor 4 torque (Newton Meters)
float	amps_5	Motor 5 torque (Newton Meters)
float	amps_6	Motor 6 torque (Newton Meters)
float	amps_7	Motor 7 torque (Newton Meters)
float	amps_8	Motor 8 torque (Newton Meters)
float	amps_9	Motor 9 torque (Newton Meters)
float	amps_10	Motor 10 torque (Newton Meters)
float	amps_11	Motor 11 torque (Newton Meters)
float	amps_12	Motor 12 torque (Newton Meters)

4.5.7 Request ACK

This message shall be sent by the ACU in response to certain non-pointing command messages as defined in Table 5. The purpose of this message is to tell the PC that the ACU has received the message. The message consists of a message header and one uint32 that is provided for future expansion as shown in Table 21.

Table 21 – Request Acknowledgment Message Definition

Type	Name	Description
	header	Message header
uint32	Reserved	

4.5.8 Status Request

This message may be sent by the PC when it wants to request a specific status without sending a pointing command. The message is defined in Table 22.

Table 22 – Status Request Message Definition

Type	Name	Description
	header	Message header
uint32	status	Status request word

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE
7 December 2010

2. REPORT TYPE
Project Report

3. DATES COVERED *(From - To)*

4. TITLE AND SUBTITLE
Interface Control Document between the Radio Astronomy Pointing Computer (PC) and the HUSIR Antenna Control Unit (ACU)

5a. CONTRACT NUMBER
FA8721-05-C-0002

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
James V. Eshbaugh

5d. PROJECT NUMBER
1247

5e. TASK NUMBER
111

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) AND ADDRESS(ES)
MIT Lincoln Laboratory
244 Wood Street
Lexington, MA 02420-9108

8. PERFORMING ORGANIZATION REPORT NUMBER
HUSIR-7

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
850 ELSG/NS
11 Barksdale Street
Building 1614
Hanscom AFB, 01731-1700

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)
ESC-TR-2010-070

12. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT
The interface between the Haystack antenna control unit (ACU) and the pointing computer is defined. The pointing computer provides the ACU with time tagged azimuth and elevation commands, and the ACU provides current antenna position and status. The defined interface uses a dedicated Ethernet connection between the ACU and pointing computer, allowing for pointing computers of any type and location if required.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			19b. TELEPHONE NUMBER *(include area code)*
Unclassified	Unclassified	Unclassified	Same as report	26	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39.18

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