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Integrated Autonomous Flight Termination Unit (IAFTU) Wrapper

User's Manual

October 9, 2023

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TABLE OF CONTENTS

1	Copyright, Trademarks, Distribution Notices.....	7
1.1	Copyright	7
1.2	Trademarks.....	7
1.3	Notice Of Controlled Unclassified Information.....	7
2	Document Control.....	8
2.1	Revision History.....	8
2.2	Approvals.....	8
2.3	Points of Contact.....	9
2.4	Service Desk.....	9
3	Acronyms and Abbreviations.....	10
4	General Information	11
5	General Notes/Disclaimers/Warnings.....	12
6	Customer Support.....	12
7	Integrated Autonomous Flight Termination Unit (IAFTU) Overview.....	13
7.1	IAFTU Specification Summary	14
8	IAFTU Electrical Connection Functional Description	16
8.1	IAFTU Connector and Cable ICD	20
9	Data Routing.....	23
10	Telemetry	24
10.1	Telemetry Message Header.....	24
10.2	Telemetry Message Types	26
10.3	IAFTU Status Message	27
10.4	CASS Data Message	32
10.5	Navigation Solution Message	33
10.6	Analog Housekeeping Message	33
10.7	Analog-to-Digital Converter (ADC) Channels	39



10.8	Talkback Channels	42
10.9	Report Message	43
11	Command.....	44
11.1	User Commands	45
11.2	Operation Procedure	46
11.3	Hold operation procedure	47
11.4	Safe operation procedure	47
11.5	Test Watchdog.....	47
11.6	Test watchdog procedure	48
12	Navigation Sensors.....	48
12.1	IAFTU necessary JAVAD message types	48
12.2	JAVAD header message format.....	49
12.3	JAVAD [rE] message format	49
12.4	JAVAD [rV] message format.....	51
12.5	JAVAD [RE] message format.....	53
12.6	JAVAD [ER] message format.....	54
12.7	NovAtel OEM6/7 Sensor Messages.....	54
12.8	NovAtel message IDs	55
12.9	NovAtel header message format	56
12.10	NovAtel BESTXYZ message format	57
12.11	NovAtel PSRDOP2 message format	59
12.12	BAE Navstrike 3.7 & M-Code.....	60
13	IAFTU Boot Sequence And Power On Self-Test	67
14	Cbit Operation	71
14.1	IAFTU NAND Byte/Block Offsets.....	71
15	Sysconfig Data	73
15.1	System Configuration (Sysconfig) Data Format.....	73



15.2	Flight Configuration Data Format.....	74
16	Installing Configuration File	75
17	Installation Guide	78
18	Helpful Operational Hints	79
19	Report Messages	81
19.1	Report message categories.....	81
19.2	Event information report messages (5000-5999).....	82
19.3	Initialization information report messages (6000 – 6999).....	85
19.4	Recoverable errors report messages (7000 – 7999)	86
19.5	Unrecoverable Fatal report messages (8000 – 8999).....	91

TABLE OF FIGURES

Figure 1:	Integrated Autonomous Flight Termination Unit (IAFTU)	11
Figure 2:	Integrated Autonomous Flight Termination Unit Mounting Plate	11
Figure 3:	IAFTU Functional Block Diagram	13

TABLE TABLES

Table 1:	Revision History.....	8
Table 2:	Approvals.....	8
Table 3:	Points of Contact.....	9
Table 4:	Acronyms and Abbreviations.....	10
Table 5:	IAFTU Specification Summary	15
Table 6:	IAFTU Electrical Connector Pinout and Description	19
Table 7:	IAFTU Connector and Cable ICD	22
Table 8:	Telemetry Header Format.....	24
Table 9:	- Telemetry Message Types.....	26
Table 10:	Telemetry IAFTU Status Message Format	32



Table 11: Telemetry CASS Data Message Format 32

Table 12: Telemetry Navigation Solution Message Format..... 33

Table 13: Telemetry Analog Housekeeping Message Format 39

Table 14: ADC Conversion Values 42

Table 15: Talkback Channels 43

Table 16: Telemetry Report Message Format 43

Table 17: User Command Message Format..... 44

Table 18: List of User Commands 45

Table 19: Startup Operation Procedure 47

Table 20: Hold Operation Procedure..... 47

Table 21: Safe Operation Procedure 47

Table 22: Test Watchdog Procedure..... 48

Table 23: IAFTU Necessary JAVAD Message Types..... 48

Table 24: JAVAD Header Message Format..... 49

Table 25: JAVAD [rE] Message Format 50

Table 26: JAVAD [rV] Message Format 53

Table 27: JAVAD [RE] Message Format 53

Table 28: JAVAD [ER] Message Format 54

Table 29: NovAtel Message IDs 55

Table 30: Novatel Sync Bytes..... 55

Table 31: NovAtel Header Message Format 56

Table 32: Novatel Bestxyz Message Format 58

Table 33: NovAtel PSRDOP2 Message Format..... 59

Table 34: IAFTU Necessary Navstrike Message Types..... 60

Table 35: IAFTU NAND Byte/Block Offsets..... 71

Table 36: System Configuration (Sysconfig) Data Format..... 73

Table 37: Flight Configuration Data Format..... 74

Table 38: Report Message Categories..... 81



Table 39: Event Information Report Messages (5000-5999)85

Table 40: Initialization Information Report Messages (6000 – 6999)86

Table 41: Recoverable Errors Report Messages (7000 – 7999).....91

Table 42: Unrecoverable Fatal Report Messages (8000 – 8999)100

TABLE OF CODE BLOCKS

Code Block 1: Calculate Checksum.....25

Code Block 2: Converting ADC Channel Raw Value to Actual Value.....39

Code Block 3: Converting ADC Channel Raw Value to Actual Value.....39



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2 DOCUMENT CONTROL

2.1 REVISION HISTORY

REV LETTER	REVISION	DATE	AUTHOR	DOCUMENT CHANGES
	1.0	09/05/2023	Kleber Valencia	Initial Release
	1.1	10/09/2023	Stephen Mitchell	Layout, Format, Editing. Content Review and Correction. Structural Analysis and Enhancement.
	1.2	10/12/2023	John Rizzo	Wiring Update J4,

Table 1: Revision History

2.2 APPROVALS

NAME	TITLE	ROLE	SIGNATURE	DATE
John Rizzo	Sr. Vice President, Business/Programs	Program Manager		6/24/24
Kleber Valencia	Vice President, Engineering	Design Architect		6/24/24

Table 2: Approvals



2.3 POINTS OF CONTACT

NAME	TITLE	EMAIL	CONTACT NUMBER
John Rizzo	Sr. Vice President, Business/Programs	jrizzo@sagrad.com	
Kleber Valencia	Vice President, Engineering	kvalencia@sagrad.com	
Tony Crosthwaite	Vice President, Operations	tcrosthwaite@sagrad.com	321-726-9400

Table 3: Points of Contact

2.4 SERVICE DESK

In the event of a question about the operation of the systems, users should contact the Sagrad Service Desk at +1 (321) 726-9400 or via email: sales@sagrad.com



3 ACRONYMS AND ABBREVIATIONS

Units of measure and some terms commonly understood within the subject disciplines have been abbreviated in the body of this document without callout but are included among the following.

ACRONYM	DEFINITION
ADC	Analog to Digital Converter
CASS	Core Autonomous Safety Software
ESD	Electrostatic Discharge
FPGA	Field Programmable Gate Array
FSBL	First Stage Boot Loader
GPIO	General Purpose Input Output
GSE	Ground Support Equipment
LSB	Least Significant Bi
MDL	Mission Data Load
POC	Point of Contact
SDL	SDL file
SV	Satellite Vehicles

Table 4: Acronyms and Abbreviations

4 GENERAL INFORMATION

The **SG901-1250 IAFTU** is an integrated system for independent flight vehicle termination, utilizing configurable software-based rules and data-redundant navigational sensors. The device complies with a tailored version of the [Range Commander Council \(RCC\) RCC 319-19](#) requirements. The IAFTU is powered from a **22-36 VDC** input, while each termination output can source up to **100mA**.

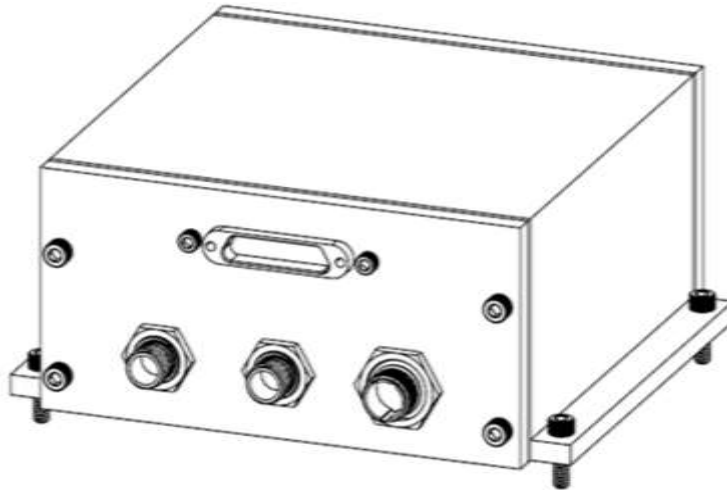


Figure 1: Integrated Autonomous Flight Termination Unit (IAFTU)

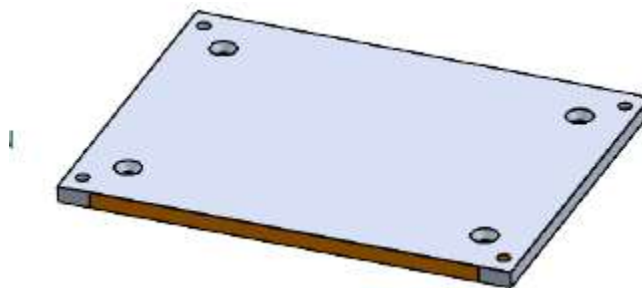


Figure 2: Integrated Autonomous Flight Termination Unit Mounting Plate



5 GENERAL NOTES/DISCLAIMERS/WARNINGS

This manual contains information about the **physical, mechanical, electrical, and software characteristics, installation, and operation** of the SG901-1250 IAFTU.

Each **SG901-1250** is supplied with the following:

- **Four (4)** each **8-32** mounting bolts and associated lock washers
- **One (1)** each **pre-paid binary** license for VxWorks

Flight use of an **IAFTU** requires approval from the user's range authority.

The IAFTU is an International Traffic in Arms Regulation (ITAR) controlled item with US Export restrictions.

6 CUSTOMER SUPPORT

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7 INTEGRATED AUTONOMOUS FLIGHT TERMINATION UNIT (IAFTU) OVERVIEW

The SG901-1250 executes via the **Core Autonomous Safety Software (CASS) Operational Release 3** within a Sagrad-developed “wrapper” software supported by **VxWorks**. This wrapper has checks not to allow a user to operate the AFSS unless in the nominal range of operation. The **IAFTU** has a **minimum allowed enable voltage of 22V** and a **maximum allowed enable voltage of 36V**. The **IAFTU** processor will be turned on at **15V** and can withstand input voltages up to **45V** without damage.

The **IAFTU** has two forms of voltage protection: **reverse and overvoltage protection**. The device is protected from reverse voltage input via two independent circuits, a parallel two **100-volt diode** package, and a two **P-Chan** series MOSFET. Off-nominal voltage is minimized by the internal **5V DC/DC** converter and the unit not allowing “Enable” in over-voltage conditions. The unit goes into **undervoltage shutdown** in the case of a voltage input below 15V. The unit’s **overvoltage protection** will trigger voltages over **51V** and will turn off.

Figure 3: IAF TU Functional Block Diagram provides a functional block diagram of the **IAFTU's two main circuit boards** – the **Input/Output** and **Main circuit boards** – and summarizes the overall input and output interfaces of the **IAFTU**. Table 5: IAF TU Specification Summary summarizes the operating specifications and interface attributes of the IAF TU.

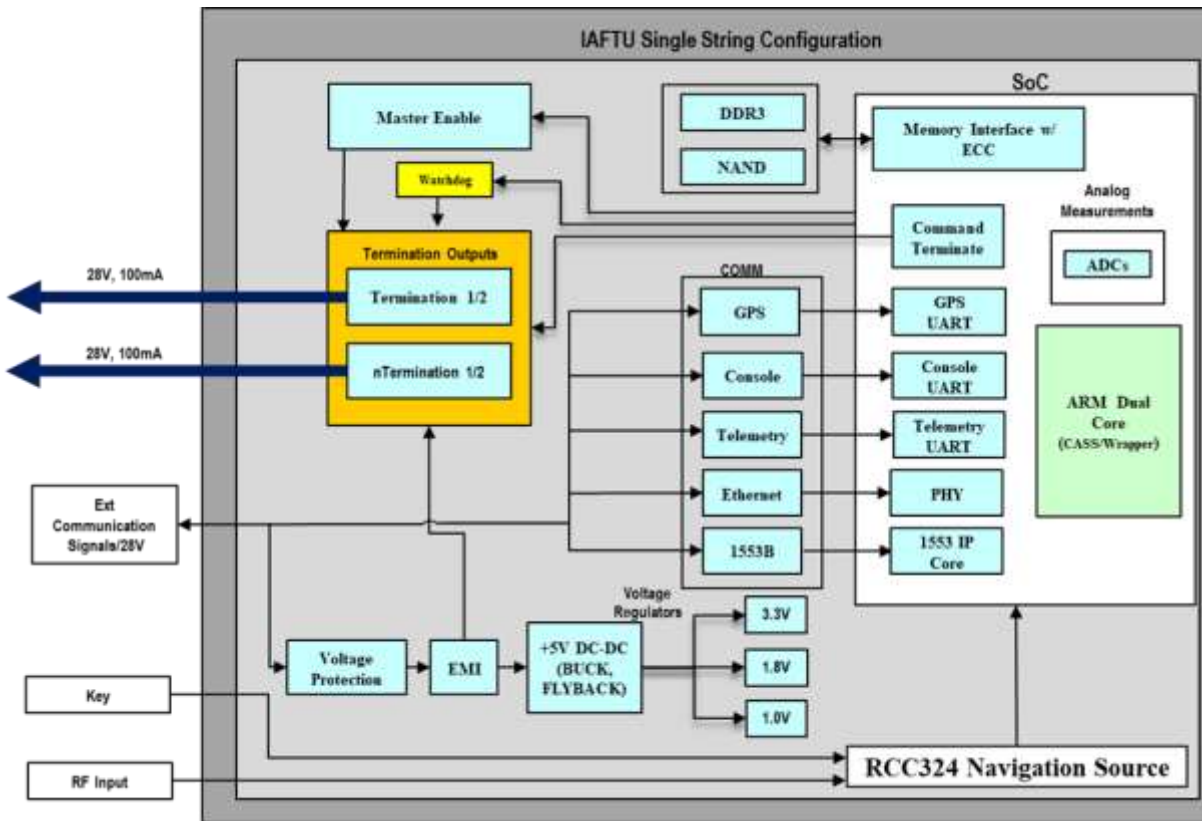


Figure 3: IAF TU Functional Block Diagram



7.1 IAFTU SPECIFICATION SUMMARY

PARAMETER	TEST CONDITION / COMMENT	MIN.	TYP.	MAX	UNITS
General Operating Conditions					
Supply Voltage (Operating)		22	28		VDC
Operating Power	Max when "Master Enable" is active	7	11	16	Watts
Max Supply Voltage without damage		-45		51	VDC
General Operating Conditions					
Temperature	Normal Operating Temperature	-24		61	°C
	Storage Temperature	0		45	°C
Shelf Life	From date of manufacture		5		Years
Mechanical					
Dimensions	Length		4.5		Inches
	Width		4.5		Inches
	Height		2.2		Inches
Weight	Without cables			2.0	Lbs
	With cables (20 feet)		20		Lbs
Cable Weight	Cable weight per foot		1		Lbs
Mounting (IAFTU) (see Figure 3)	Four (4) corner mounting holes	0.150" DIA; supplied with 8-32 mounting bolts			
Interface Connectors (Part Number) NOTE: See Figure 1.	J1: GPS	SMA			
	J2: Termination	Glenair 801-011-07M6-4SA			
	J3: NOT Termination	Glenair 801-011-07M6-4SB			
	J4: Communication	Glenair M83513			
	J5: Crossover	Glenair 801-011-07M7-10SA			



Parameter	Test Condition / Comment	Min.	Typ.	Max	Units
Interface Signals					
Interface Connector (Signals)* *NOTE: See section 8	J1 GPS: SMA RF Cable		50		Ω
	J2: Term 1 & 2 Constant (DC) (Normally Off)			0.1	Amps
	J3: nTERM 1& 2 (Normally On) Constant (DC)			0.1	Amps
	J4 Comm: Console interface RS-422			115200	baud
	J4 Comm: NAV1 RS-422			115200	baud
	J4 Comm: NAV2 RS-422			115200	baud
	J4 Comm Telemetry: RS-422			115200	baud
	J4 Comm: Lift-off Detect Input (Redundant Inputs)	22		36	VDC
	J4 Comm: Input Power	22	28	36	VDC
	J4 Comm: Umbilical Disarm Input (Redundant Inputs)	22		36	VDC
	J4 Comm: Ethernet (802.3ab, over twisted pair)			1000	Mbits/s
	J5: Internal / External Comm (RS-422)			115200	baud
	J5: Watchdog External Health (discrete) Input	9		34	VDC
	J5: Watchdog External Health (discrete) Output		28		VDC

Table 5: IAFTU Specification Summary



8 IAFTU ELECTRICAL CONNECTION FUNCTIONAL DESCRIPTION

The **five (5) electrical connectors** of the **IAFTU** are identified and described in Table 6: IAFTU Electrical Connector Pinout and Description, with **cabling wire identification** detailed in Table 6 below. **NOTE: J3** is capped and unused.

IAFTU ELECTRICAL CONNECTOR PINOUT AND DESCRIPTION

CONNECTOR DESIGNATOR	SIGNAL	PIN	DESCRIPTION
J1 GPS	GPS RF	1	RF connection to integrated navigation source.
J2 TERMINATION (TERM)	TERM1 SIG	1	100mA constant current output. Will provide current once CASS has recommended termination.
	TERM1 RTN	4	Return signal of output load
	TERM2 SIG	2	100mA constant current output. Will provide current once CASS has recommended termination.
	TERM2 RTN	3	Return signal of output load
J3 NOT TERMINATION (nTERM)	nTERM1 SIG	1	100mA constant current output. Will provide current once CASS logic enable and master enable commands have been sent. Will remove the current once CASS has recommended termination.
	nTERM1 RTN	4	Return signal of output load
	nTERM2 SIG	2	100mA constant current output. Will provide current once CASS logic enable and master enable commands have been sent. Will remove the current once CASS has recommended termination.
	nTERM2 RTN	3	Return signal of output load
J4 COMMUNICATION (Comm)	Console TX+ (RS422)	11	Transmission and receiver sides of the RS-422 line for console communication to GSE over umbilical. Default baud rate of 115200, no flow control. Port TyCo 3.
	Console TX- (RS422)	28	
	Console RX+ (RS422)	12	
	Console RX- (RS422)	29	
	Telem TX+ (RS422)	5	Transmission and receiver sides of the RS-422 line to transmit AFTU telemetry data and receive user commands. Default baud rate of



CONNECTOR DESIGNATOR	SIGNAL	PIN	DESCRIPTION
	Telem TX- (RS422)	22	115200, no flow control. Port tyCo4. Console will be sent once VxWorks Application starts.
	Telem RX+ (RS422)	6	
	Telem RX- (RS422)	23	
	Ethernet BI_DA+	7	1000Mbps ethernet connection. Default configuration to stream telemetry. It can accept navigation messages and user commands.
	Ethernet BI_DA-	24	
	Ethernet BI_DB+	8	
	Ethernet BI_DB-	25	
	Ethernet BI-DC+	9	
	Ethernet BI-DC-	26	
	Ethernet BI-DD+	10	
	Ethernet BI-DD-	27	
	NAV1 PPS	2	External Navigation 1 pulse-per-second input.
	NAV1 TX+ (RS422)	3	Transmission and receiver sides of the RS-422 lines to receive navigation data from the Navigation 1 sensor.
	NAV1 TX- (RS422)	20	
	NAV1 RX+ (RS422)	4	
	NAV1 RX- (RS422)	21	
	NAV2 PPS	17	External Navigation 2 pulse-per-second input.
	NAV2 TX+ (RS422)	15	Transmission and receiver sides of the RS-422 lines to receive navigation data from the Navigation 2 sensor.
	NAV2 TX- (RS422)	32	
	NAV2 RX+ (RS422)	16	
	NAV2 RX- (RS422)	33	
	Liftoff_A SIG	37	0 to 34 volts and ground supplied by vehicle (Umbilical). Nominally



CONNECTOR DESIGNATOR	SIGNAL	PIN	DESCRIPTION
	Liftoff_A RTN	38	28V. Loaded 10kΩ. Used to indicate Liftoff to the IAFTU and is the first inhibit used by the MDL.
	Liftoff_B SIG	39	0 to 34 volts and ground supplied by vehicle (Umbilical). Nominally 28V. Loaded 10kΩ. Used to indicate Liftoff to the IAFTU and is the second inhibit used by the MDL.
	Liftoff_B RTN	40	
	UMB_SAFE_A SIG	41	0 to 34 volts and ground supplied by vehicle (Umbilical). Nominally 28V. Loaded 10kΩ. Expected to be a differential signal. Applying voltage will remove termination voltage or "safe" the unit. Requires both umbilical safe A and B to safe the IAFTU.
	UMB_SAFE_A RTN	42	
	UMB_SAFE_B SIG	43	0 to 34 volts and ground supplied by vehicle (Umbilical). Nominally 28V. Loaded 10kΩ. Expected to be a differential signal. Applying voltage will remove the unit's termination voltage or 'safe.' Requires both umbilical safe A and B to safe the IAFTU.
	UMB_SAFE_B RTN	44	
	28V DC	18,3 4	22 to 36 volts DC input to IAFTU.
	PWR GND	19,3 5	
	No Connect	1	
	No Connect	47	
	No Connect	36	
	No Connect	45	
	No Connect	46	
	No Connect	48	
	No Connect	49	
	No Connect	50	
	No Connect	51	
	No Connect	13	
	No Connect	30	
	No Connect	14	



CONNECTOR DESIGNATOR	SIGNAL	PIN	DESCRIPTION
J5 Crossover	No Connect	31	
	Local IAFTU Health Out SIG	3	Isolated 22 to 34 volts discrete indicates to the other chassis the local IAFTU health.
	Local IAFTU Health Out RTN	7	Isolated 22 to 34 volts discrete indicates to the other chassis the local IAFTU health return.
	Redundant IAFTU Health In SIG	2	Isolated 22 to 34 volts discrete indicates to the local IAFTU the status of the redundant IAFTU.
	Redundant IAFTU health In RTN	6	Isolated 22 to 34 volts discrete indicates to the local IAFTU the status of the redundant IAFTU return.
	Internal NAV TX+ (RS422)	4	Transmission and receiver sides of the RS-422 lines send and receive navigation data from local and redundant IAFTU internal navigation sources.
	Internal NAV1 TX- (RS422)	8	
	Internal NAV1 RX+ (RS422)	5	
	Internal NAV1 RX- (RS422)	9	
	No Connect	1	
No Connect	10		

Table 6: IAFTU Electrical Connector Pinout and Description



8.1 IAFTU CONNECTOR AND CABLE ICD

CONNECTOR DESIGNATOR	SIGNAL	PIN		COLOR
J1 Antenna	Antenna 50Ω	1		
J2 TERM	TERM1 SIG	1	TWISTED	ORG
	TERM1 RTN	4		BLK
	TERM2 SIG	2	TWISTED	BLU
	TERM2 RTN	3		BLK
J3 nTERM	nTERM1 SIG	1	TWISTED	ORG
	nTERM1 RTN	4		BLK
	nTERM2 SIG	2	TWISTED	BLU
	nTERM2 RTN	3		BLK
J4 (Comm)	Console TX+ (RS422)	11	TWISTED	YEL
	Console TX- (RS422)	28		BLK
	Console RX+ (RS422)	12	TWISTED	RED
	Console RX- (RS422)	29		BLK
	Telem TX+ (RS422)	5	TWISTED	BLU
	Telem TX- (RS422)	22		BLK
	Telem RX+ (RS422)	6	TWISTED	GRN
	Telem RX- (RS422)	23		BLK
	Ethernet BI_DA+	7	TWISTED	WHT
	Ethernet BI_DA-	24		GRN
	Ethernet BI_DB+	8	TWISTED	WHT
	Ethernet BI_DB-	25		ORG
	Ethernet BI-DC+	9	TWISTED	BLU
	Ethernet BI-DC-	26		WHT
	Ethernet BI-DD+	10	TWISTED	BRN
	Ethernet BI-DD-	27		WHT



CONNECTOR DESIGNATOR	SIGNAL	PIN		COLOR
	NAV1 PPS	2		TBD
	NAV1 TX+ (RS422)	3	TWISTED	GRY
	NAV1 TX- (RS422)	20		BLK
	NAV1 RX+ (RS422)	4	TWISTED	VIO
	NAV1 RX- (RS422)	21		BLK
	NAV2 PPS	17		TBD
	NAV2 TX+ (RS422)	15	TWISTED	ORG
	NAV2 TX- (RS422)	32		BLK
	NAV2 RX+ (RS422)	16	TWISTED	BRN
	NAV2 RX- (RS422)	33		BLK
	Liftoff_A SIG	37	TWISTED	ORG
	Liftoff_A RTN	38		BLK
	Liftoff_B SIG	39	TWISTED	YEL
	Liftoff_B RTN	40		BLK
	UMB_SAFE_A SIG	41	TWISTED	GRN
	UMB_SAFE_A RTN	42		BLK
	UMB_SAFE_B SIG	43	TWISTED	BLU
	UMB_SAFE_B RTN	44		BLK
	28V DC	18,34	TWISTED	RED
	PWR GND	19,35		BLK
	No Connect	47	TWISTED	TBD
	No Connect	48		TBD
	No Connect	49	TWISTED	TBD
	No Connect	50		TBD
	No Connect	13	TWISTED	GRN
	No Connect	30		BLK



CONNECTOR DESIGNATOR	SIGNAL	PIN		COLOR
	No Connect	14	TWISTED	BLU
	No Connect	31		BLK
J5 (Crossover)	Local IAF TU Health Out SIG	3	TWISTED	YEL
	Local IAF TU Health Out RTN	7		BLK
	Redunant IAF TU Health In SIG	2	TWISTED	ORG
	Redunant IAF TU health In RTN	6		BLK
	WD Timer Health Out SIG	4	TWISTED	BLU
	WD Timer Health Out RTN	8		BLK
	WD Timer Health IN SIG	5	TWISTED	GRN
	WD Timer Health IN RTN	9		BLK
	No Connect	1	NA	NA
	No Connect	10	NA	NA

Table 7: IAF TU Connector and Cable ICD

NOTE:

Wire color-coding is for a Sagrad SG901-1251 cable harness set.



9 DATA ROUTING

The following describes the **recommended operations concept** for different **IAFTU data reporting**.

Console: **RS-422 to ground support equipment (GSE)** – for GSE to record data stream.

Messages and commands are in **ASCII format**, and only **boot-up** and **maintenance commands** are sent from GSE; only **periodic status messages** are sent from the IAFTU to GSE via the **Console data stream**.

The connection is **115200 bps** with no flow control – data may be lost if GSE cannot maintain this rate.

Telemetry: **Ethernet or RS-422 to ground support equipment (GSE)** – for GSE to record data stream.

All messages are sent in **binary format** and must be decoded to be human-readable. All messages are sent at **default data rates**. If the connection is over **RS-422**, then the connection is 115200 bps with no flow control, or if the connection is over ethernet, then the connection is **1000Mbps** – data may be lost if the vehicle cannot maintain this rate.

Umbilical: **Ethernet UDP to/from ground support equipment** -- GSE shall record data stream.

Connection is expected to be available during **countdown/pre-flight** until at least the first motion of the vehicle.

All messages are sent at **default data rates**, with commands being sent from GSE to **IAFTU(s)**. Connection is **100Mbps** ethernet – data may be lost if GSE cannot maintain this rate.

External GPS: **RS-422 or via Ethernet** to onboard vehicle equipment.

Unless tailored otherwise, all messages are sent at **default data rates**; no command uplink exists. The connection is expected to be available during the countdown/pre-flight until the end of the tracking mission.

If the connection is over **RS-422**, then the connection is **115200 bps** with no flow control, or if the connection is over ethernet, then the connection is 1000Mbps – data may be lost if the vehicle cannot maintain this rate.



10 TELEMETRY

This section specifies the **type** and **content** of the various **telemetry messages** issued by the **IAFTU flight software**. The IAFTU provides a **serial data interface** over an **RS-422** at **115200 baud**. Various **asynchronous telemetry messages** are sent. The messages are sent in **header/data-segment** pairs.

Explanations for each column in the subsections are as follows:

- The **byte number** in the **Byte Offset column** is zero-based, and the most significant byte first.
- The **bit number** in the **byte offset column** is zero-based, and the least significant bit first.
- The **byte arrangement** in each data field is the most significant byte first.
- The **32-bit floating point** in the **Data Type column** is the **IEEE 754 single precision floating point**. The **64-bit floating point** in the **Data Type column** is the **IEEE 754 double precision floating point**.

10.1 TELEMETRY MESSAGE HEADER

Each message includes a **16-byte header**, which can be used to provide **frame synchronization**, **error checking**, and **descriptive data** used to decode the data segment.

TELEMETRY HEADER FORMAT

BYTE OFFSET	DESCRIPTION	DATA TYPE
0	Synchronous flag is used for flagging the start of a message header. Always "\$".	8-bit character
1	Telemetry format version. Always "B".	8-bit character
2	Checksum of the header after this and the body data. See the Checksum section.	16-bit unsigned integer
4	The time when data is framed in the number of GPS seconds since the beginning of the week.	64-bit floating point
12	Message type; see Table 9: - Telemetry Message Types section.	8-bit unsigned integer
13	Identification of a flight processor generating this data. 0 or 1 = Flight processor ID (AFSS ID). 255 = All processors. Otherwise = Unused.	8-bit unsigned integer
14	Byte count of the data segment, starting after this.	16-bit unsigned integer

Table 8: Telemetry Header Format

CHECKSUM

```
unsigned short computeChecksum(const char buffer[],
const unsigned int buffer_size)
{
    unsigned int checksum = 0;
    for (unsigned int loop_i = 0; loop_i < buffer_size; loop_i += 2)
    {
        if ((loop_i + 1) < buffer_size) // At least two bytes left.
        {
            checksum += (
                ((static_cast<unsigned int>(buffer[loop_i + 0]) & 0xffU) << 8) |
                ((static_cast<unsigned int>(buffer[loop_i + 1]) & 0xffU) << 0)
            );
        }
        else // One byte left.
        {
            checksum += (
                ((static_cast<unsigned int>(buffer[loop_i + 0]) & 0xffU) << 8)
            );
        }
    } // For loop_i.

    checksum = (~checksum) + 1; // Two's complement.

    return static_cast<unsigned short>(checksum & 0xffffU);
} // Function computeChecksum.
```

Code Block 1: Calculate Checksum



10.2 TELEMETRY MESSAGE TYPES

TYPE (DEC)	TYPE (HEX)	DESCRIPTION	DATA SIZE (BYTES)	FREQUENCY (HZ)	BANDWIDTH (BITS PER SECOND)
16	0x10	IAFTU Status Message	42	10	4,200
17	0x11	CASS Data Message	up to 256	10	up to 25,600
20	0x14	Navigation Solution Message for navigation #0	42	up to 20	up to 8,400
21	0x15	Navigation Solution Message for navigation #1	42	up to 20	up to 8,400
22	0x16	Navigation Solution Message for navigation #2	42	up to 20	up to 8,400
50	0x32	Analog Housekeeping Message	87	10	8,700
51	0x33	User Command Message	13	approx. 1	approx. 130
55	0x37	Report Message	up to 256	approx. 5	approx. 12,800

Table 9: - Telemetry Message Types

The **navigation message number** is assigned by the order the sensors appear in the **MDL**. Verification of a sensor being initialized can be found in console messages **6227** and **6220**.

The **IAFTU** ignores many **navigation solutions** if **CASS** never ingests them. These messages will not be transmitted through **telemetry** by the **IAFTU**.

A few key items from **telemetry** will signify a fully functional **IAFTU**. Firstly, messages **16**, **17**, and **50** give general health messages that allow the user to gauge if there are any errors or unexpected values. Please use the tables below to see what data is contained in each message to verify that expected values are returned. Secondly, message **21** and **22** can be used to verify that the receivers being fed into the **IAFTU** are healthy and given good information. For example, messages **21** and **22** will return the number of satellites the receiver uses to create the solutions.

The **Data Size** column includes the header and body.

The **Bandwidth** column is calculated based on the **Max Data Size** column plus two overhead bits (start and stop bits) associated with each byte transfer. The total downlink bandwidth with three navigation sensors at **20 Hz** is approximately **76,500 bits per second per IAFTU**. The total uplink bandwidth is approximately **130 bits per second per IAFTU**.



The data segment for each message type is described in detail in subsequent sections.

10.3 IAFTU STATUS MESSAGE

The AFTS **Binary status message** comprises health and status data from various application segments. The **AFTS Core Autonomous Safety Software** encodes status information into a byte-array made available at the end of each **Update** call made by the host executive application. The host executive appends this data to the processor **temperature** and **termination circuit status data** to form the data segment for this message.

TELEMETRY IAFTU STATUS MESSAGE FORMAT

BYTE OFFSET	DESCRIPTION	DATA TYPE
0	Telemetry message header; see Telemetry Message Header section.	H-byte byte array
H+0	Cycle count, run from 0 through 255, and then repeat.	8-bit unsigned integer
H+1, bit 7	Health status from other IAFTU. Same as EXT-HLTH in the Navigation Solution Message section. 0 = External health sensed. 1 = No external health sensed.	1-bit flag
H+1, bit 6	Watchdog health B. Same as WD-B-nHLTH in Navigation Solution Message section. 0 = Has not been reset. 1 = Has been reset.	1-bit flag
H+1, bit 5	Watchdog health A. Same as WD-A-nHLTH in the Navigation Solution Message section. 0 = Has not been reset. 1 = Has been reset.	1-bit flag
H+1, bit 4	Watchdog has commanded termination (failsafe TERM). 0 = Watchdog has not command termination. 1 = Watchdog has command termination.	1-bit flag
H+1, bit 3	State of the nTERM 2 output. 0 = Disabled, "enabled and commanded," or indeterminate. 1 = "Enabled but not commanded". WARNING: This may not be accurate after mission safe; see the Analog Housekeeping Message message (#50) for ADC values.	1-bit flag



BYTE OFFSET	DESCRIPTION	DATA TYPE
H+1, bit 2	State of the nTERM 1 output. 0 = Disabled, "enabled and commanded," or indeterminate. 1 = "Enabled but not commanded". WARNING: This may not be accurate after mission safe; see the Analog Housekeeping Message message (#50) for ADC values.	1-bit flag
H+1, bit 1	State of the TERM 2 output. 0 = Disabled, "enabled but not commanded," or indeterminate. 1 = "Enabled and commanded".	1-bit flag
H+1, bit 0	State of the TERM 1 output. 0 = Disabled, "enabled but not commanded," or indeterminate. 1 = "Enabled and commanded".	1-bit flag
H+2, bit 7	Test mode condition. 0 = Disabled. 1 = Enabled.	1-bit flag
H+2, bit 6	Liftoff detection B. Same as LODL-TTB in the Navigation Solution Message section. 0 = No signal, liftoff. 1 = Has signal, not liftoff.	1-bit flag
H+2, bit 5	Liftoff detection A. Same as LODL-TTA in the Navigation Solution Message section. 0 = No signal, liftoff. 1 = Has signal, not liftoff.	1-bit flag
H+2, bit 4	Reserved for future umbilical safe disconnected B. Same as UMB-SAFE-DIS-B-TB in Navigation Solution Message section. This field is always zero.	1-bit flag
H+2, bit 3	Reserved for future umbilical safe disconnected A. Same as UMB-SAFE-DIS-A-TB in Navigation Solution Message section. This field is always zero.	1-bit flag
H+2, bit 2	State of the Watchdog transceiver. 0 = Disabled or indeterminate. 1 = Enabled.	1-bit flag



BYTE OFFSET	DESCRIPTION	DATA TYPE
H+2, bit 1	State of the Watchdog circuit. 0 = Disabled or indeterminate. 1 = Enabled.	1-bit flag
H+2, bit 0	State of the termination circuit. 0 = Disabled or indeterminate. 1 = Enabled.	1-bit flag
H+3	Reserved; former internal GPS status bits.	8-bit unsigned integer
H+4, bit 7	State of the gate for the low side of the nTERM 2 output. 0 = Disabled, "enabled and commanded," or indeterminate. 1 = "Enabled but not commanded".	1-bit flag
H+4, bit 6	State of the gate for the high side of the nTERM 2 output. 0 = Disabled, "enabled and commanded," or indeterminate. 1 = "Enabled but not commanded".	1-bit flag
H+4, bit 5	State of the gate for the low side of the nTERM 1 output. 0 = Disabled, "enabled and commanded," or indeterminate. 1 = "Enabled but not commanded".	1-bit flag
H+4, bit 4	State of the gate for the high side of the nTERM 1 output. 0 = Disabled, "enabled and commanded," or indeterminate. 1 = "Enabled but not commanded".	1-bit flag
H+4, bit 3	State of the gate for the low side of the TERM 2 output. 0 = Disabled, "enabled but not commanded," or indeterminate. 1 = "Enabled and commanded".	1-bit flag
H+4, bit 2	State of the gate for the high side of the TERM 2 output. 0 = Disabled or indeterminate. 1 = "Enabled but not commanded" or "enabled and commanded."	1-bit flag
H+4, bit 1	State of the gate for the low side of the TERM 1 output. 0 = Disabled, "enabled but not commanded," or indeterminate. 1 = "Enabled and commanded".	1-bit flag



BYTE OFFSET	DESCRIPTION	DATA TYPE
H+4, bit 0	State of the gate for the high side of the TERM 1 output. 0 = Disabled or indeterminate. 1 = "Enabled but not commanded" or "enabled and commanded."	1-bit flag
H+5	Reserved; former ADC channel index and data.	24-bit unsigned integer
H+8, bit 7	Liftoff flag; based on the CASS database variable TFLO. 0 = Lift-off is not detected; TFLO <= 0.0. 1 = Lift-off is detected; TFLO > 0.0.	1-bit flag
H+8, bit 6	Destruct condition in the CASS. 0 = Destruct function is not recommended. 1 = Destruct function is recommended. NOTE: This is the same as bit #5, system destruct.	1-bit flag
H+8, bit 5	System destruct condition in the CASS. 0 = Destruct function is not recommended. 1 = Destruct function is recommended.	1-bit flag
H+8, bit 4	System arm condition in the CASS. 0 = Arm function is not recommended. 1 = Arm function is recommended.	1-bit flag
H+8, bit 3	Rule processing condition in the CASS. 0 = Not in rule processing state. 1 = In rule processing state.	1-bit flag
H+8, bit 2	Rule processing logic condition in the CASS. 0 = Rule processing logic is not enabled. 1 = Rule processing logic is enabled.	1-bit flag
H+8, bit 1	IAFTU software health. 0 = Health is bad. 1 = Health is good.	1-bit flag
H+8, bit 0	Master toggle between 0 and 1 on every update. Equivalent to cycle count, mod 2.	1-bit flag
H+9, bit 7	Reserved; former number of IAFTU health tasks.	6-bit unsigned integer



BYTE OFFSET	DESCRIPTION	DATA TYPE
H+9, bit 1	Validity flag for navigation data from the CASS database variable isValidNavData. 0 = There is no valid source navigation position/velocity data. 1 = There is valid navigation position/velocity data from at least one source.	1-bit flag
H+9, bit 0	In-orbit flag; based on the CASS database variable Perigee. 0 = Vacuum perigee is at or below the surface of the earth; Perigee <= 0.0. 1 = Vacuum perigee is above the surface of the earth; Perigee > 0.0.	1-bit flag
H+10	Time since last valid reading on any sensor in hundreds of milliseconds from CASS database variable NoDataTime.	8-bit unsigned integer
H+11	Sensor latency in tens of milliseconds from CASS database variable Latency.	8-bit unsigned integer
H+12	Destruct signal timer in hundreds of milliseconds from CASS database variable DestructSignal.	8-bit unsigned integer
H+13	Reserved; former CASS green time monitor.	8-bit unsigned integer
H+14	Destruct rule count from CASS database variable dstRuleCount.	8-bit unsigned integer
H+15	Reserved; former CASS monitor bits.	16-bit unsigned integer
H+17, bit 7	Has rules safed. 1 = If CASS has recommended safe.	1-bit flag
H+17, bit 6	Number of valid sensors detected by sensor manager based on the CASS database variable ValidSensorCount.	3-bit unsigned integer
H+17, bit 3	Reserved; former CASS navigation monitor bits.	4-bit unsigned integer
H+18	Reserved; former CASS monitor bits.	16-bit unsigned integer
H+20	CASS time, seconds in GPS week.	64-bit floating point
H+28	CASS state. 0 = Created. 1 = Sensors registered. 2 = Ready for rule processing. 3 = Rule processing.	8-bit unsigned integer



BYTE OFFSET	DESCRIPTION	DATA TYPE
H+29	AFTS state. 0 = Stop processing. 1 = Boot. 2 = Initialization. 3 = Stand by. 4 = Flight enabled. 5 = End of mission. 6 = Flight termination.	8-bit unsigned integer
H+30	CPU 0 idle percentage (0 – 100%).	8-bit unsigned integer
H+31	CPU 1 idle percentage (0 – 100%).	8-bit unsigned integer
H+32	Elapsed time since the last cycle in hundreds of microseconds.	8-bit unsigned integer
H+33	Reserved.	8-bit unsigned integer

Table 10: Telemetry IAFTU Status Message Format

10.4 CASS DATA MESSAGE

Mission rules can be configured to instruct **CASS** to periodically report values of **CASS** Database variable(s). The reported data format and reporting interval are specified in the mission rules. The **Sagrad** wrapper monitors **CASS** for this content and, if provided, will provide the configured content to GSE using the message shown in Table 11: Telemetry CASS Data Message Format.

TELEMETRY CASS DATA MESSAGE FORMAT

BYTE OFFSET	DESCRIPTION	DATA TYPE
0	Telemetry message header; see Telemetry Message Header section.	H-byte byte array
H+0	CASS stream data as defined in the MDL. The size of this part is varied, but 244 bytes is the maximum. If CASS generates more data that will fit in this, the data will be truncated.	M-byte byte array

Table 11: Telemetry CASS Data Message Format

10.5 NAVIGATION SOLUTION MESSAGE

Navigation solution data for each navigation sensor is encoded into a common format for telemetry output. The source of the data is implicitly identified in the message type.

TELEMETRY NAVIGATION SOLUTION MESSAGE FORMAT

BYTE OFFSET	DESCRIPTION	DATA TYPE
0	Telemetry message header; see Telemetry Message Header section.	H-byte byte array
H+0	GPS time in the number of seconds since the beginning of the week.	64-bit floating point
H+8	Component X in earth-centered earth fixed (ECEF) Cartesian position vector in meters.	64-bit floating point
H+16	Component Y in earth-centered earth fixed (ECEF) Cartesian position vector in meters.	64-bit floating point
H+24	Component Z in earth-centered earth fixed (ECEF) Cartesian position vector in meters.	64-bit floating point
H+32	Component X in earth-centered earth fixed (ECEF) Cartesian components of velocity vector in meters per second.	64-bit floating point
H+40	Component Y in earth-centered earth fixed (ECEF) Cartesian components of velocity vector in meters per second.	64-bit floating point
H+48	Component Z in earth-centered earth fixed (ECEF) Cartesian components of velocity vector in meters per second.	64-bit floating point
H+56, bit 7	Velocity validity flag provided by the receiver.	1-bit flag
H+56, bit 6	Position validity flags provided by the receiver.	1-bit flag
H+56, bit 5	Navigation validity flag set by AFSS software upon read.	1-bit flag
H+56, bit 4	The number of GPS satellite vehicles (SVs) used in navigation solution.	5-bit unsigned integer
H+57	Position dilution of precision (PDOP), x10.	8-bit unsigned integer

Table 12: Telemetry Navigation Solution Message Format

10.6 ANALOG HOUSEKEEPING MESSAGE

The AFSS Analog data comprises GPIO and/or ADC values.



TELEMETRY ANALOG HOUSEKEEPING MESSAGE FORMAT

BYTE OFFSET	DESCRIPTION	DATA TYPE
0	Telemetry message header; see Telemetry Message Header section.	H-byte byte array
H+0	Reserved (GPIO 31-24). This field is always zero.	8-bit unsigned integer
H+1, bit 4	Reserved (GPIO 23-20). This field is always zero.	4-bit unsigned integer
H+1, bit 3	Mainboard configuration 4 (GPIO 19, MAINBOARD-CONFIG-4).	1-bit flag
H+1, bit 2	Mainboard configuration 3 (GPIO 18, MAINBOARD-CONFIG-3).	1-bit flag
H+1, bit 1	Mainboard configuration 2 (GPIO 17, MAINBOARD-CONFIG-2).	1-bit flag
H+1, bit 0	Mainboard configuration 1 (GPIO 16, MAINBOARD-CONFIG-1).	1-bit flag
H+2, bit 7	Reserved for future SAASM key status 2 (GPIO 15, GPS-RTS1). This field is always zero.	1-bit flag
H+2, bit 6	Reserved for future SAASM key status 1 (GPIO 14, GPS-RTS2). This field is always one.	1-bit flag
H+2, bit 5	Unused, former internal GPS position valid (GPIO 13, GPS-PVALID). This field is always zero.	1-bit flag
H+2, bit 4	Unused, former internal GPS error (GPIO 12, GPS-ERROR). This field is always zero.	1-bit flag
H+2, bit 3	Reserved for future umbilical safe disconnected B (GPIO 11, UMB-SAFE-DIS-B-TB). This field is always zero.	1-bit flag
H+2, bit 2	Reserved for future umbilical safe disconnected A (GPIO 10, UMB-SAFE-DIS-A-TB). This field is always zero.	1-bit flag
H+2, bit 1	Liftoff detection B (GPIO 9, LODL-TTB). 0 = No signal, liftoff. 1 = Has signal, not liftoff, at least 5 volts.	1-bit flag



BYTE OFFSET	DESCRIPTION	DATA TYPE
H+2, bit 0	Liftoff detection A (GPIO 8, LODL-TTA). 0 = No signal, liftoff. 1 = Has signal, not liftoff, at least 5 volts.	1-bit flag
H+3, bit 7	Reserved (GPIO 7). This field is always zero.	1-bit flag
H+3, bit 6	Unused, former Watchdog transceiver voltage common collector (VCC) (GPIO 6, VCCWDXCVR-TB) but replaced by ADC0_VCCWDXCVR. This field is always zero.	1-bit flag
H+3, bit 5	Unused, former Watchdog voltage common collector (VCC) (GPIO 5, VCCWD-TB) but replaced by ADC0_VCCWD. This field is always zero.	1-bit flag
H+3, bit 4	Health status from other IAFTU (GPIO 4, EXT-HLTH). 0 = External health sensed. 1 = No external health sensed.	1-bit flag
H+3, bit 3	Watchdog health B (GPIO 3, WD-B-nHLTH). 0 = Has not been reset. 1 = Has been reset.	1-bit flag
H+3, bit 2	Watchdog health A (GPIO 2, WD-A-nHLTH). 0 = Has not been reset. 1 = Has been reset.	1-bit flag
H+3, bit 1	Watchdog reset line B (GPIO 1, WD-RESET-B).	1-bit flag
H+3, bit 0	Watchdog reset line A (GPIO 0, WD-RESET-A).	1-bit flag
H+4	Number of ADC channels. This field is always 70.	8-bit unsigned integer
H+5	CH_VCCPINT. Zynq PS VCCPINT. Processing system internal logic supply voltage.	8-bit unsigned integer
H+6	CH_VCCPAUX. Zynq PS VCCPAUX. Processing system auxiliary supply voltage.	8-bit unsigned integer
H+7	CH_VCCPDRO. Zynq PS VCCPDRO.	8-bit unsigned integer
H+8	CH_CPU_TEMP. Zynq On-Chip Temperature.	8-bit unsigned integer



BYTE OFFSET	DESCRIPTION	DATA TYPE
H+9	CH_VCCINT. Zynq FPGA VCCINT. Field programmable gate array internal supply voltage.	8-bit unsigned integer
H+10	CH_VCCAUX. Zynq FPGA VCCAUX. Field programmable gate array auxiliary supply voltage.	8-bit unsigned integer
H+11	CH_MB_TEMP. Mainboard Temperature.	8-bit unsigned integer
H+12	CH_VBRAM. Zynq FPGA VBRAM. Field programmable gate array supply voltage for the block RAM memories.	8-bit unsigned integer
H+13	CH_VCCTERM. Termination circuitry supply voltage.	8-bit unsigned integer
H+14	CH_VCC1V35_VS. 1.35 reference voltage.	8-bit unsigned integer
H+15	CH_TERM1_I. Zynq TERM1 current.	8-bit unsigned integer
H+16	CH_nTERM1_I. Zynq nTERM1 current.	8-bit unsigned integer
H+17	CH_TERM1_HI. Zynq TERM1 high side voltage.	8-bit unsigned integer
H+18	CH_TERM2_HI. Zynq TERM2 high side voltage.	8-bit unsigned integer
H+19	CH_nTERM1_HI. Zynq nTERM1 high side voltage.	8-bit unsigned integer
H+20	CH_nTERM2_HI. Zynq nTERM2 high side voltage.	8-bit unsigned integer
H+21	CH_IO_TEMP. I/O board temperature.	8-bit unsigned integer
H+22	CH_VCC5V0_VS. 5V input voltage.	8-bit unsigned integer
H+23	CH_TERM2_I. Zynq TERM2 current.	8-bit unsigned integer
H+24	CH_nTERM2_I. Zynq nTERM2 current.	8-bit unsigned integer
H+25	CH_TERM1_LO. Zynq TERM1 low side voltage.	8-bit unsigned integer
H+26	CH_TERM2_LO. Zynq TERM2 low side voltage.	8-bit unsigned integer
H+27	CH_nTERM1_LO. Zynq nTERM1 low side voltage.	8-bit unsigned integer
H+28	CH_nTERM2_LO. Zynq nTERM2 low side voltage.	8-bit unsigned integer
H+29	CH_ADC0_TERM2_D_HI. SPI TERM2 high gate voltage. Less than 17 volts means open.	8-bit unsigned integer
H+30	CH_ADC0_TERM1_D_LO. SPI TERM1 low gate voltage. Less than 9 volts means open.	8-bit unsigned integer



BYTE OFFSET	DESCRIPTION	DATA TYPE
H+31	CH_ADC0_nTERM1_D_LO. SPI nTERM1 low gate voltage. Less than 9 volts means open.	8-bit unsigned integer
H+32	CH_ADC0_nTERM2_D_HI. SPI nTERM2 high gate voltage. Less than 17 volts means open.	8-bit unsigned integer
H+33	CH_ADC0_VCCTERM. SPI VCCTERM.	8-bit unsigned integer
H+34	CH_ADC0_TERM1_I. SPI TERM1 current.	8-bit unsigned integer
H+35	CH_ADC0_nTERM1_I. SPI nTERM1 current.	8-bit unsigned integer
H+36	CH_ADC0_VCC. SPI primary VCC voltage.	8-bit unsigned integer
H+37	CH_ADC0_nTERM1_D_HI. SPI nTERM1 high gate voltage. Less than 17 volts means open.	8-bit unsigned integer
H+38	CH_ADC0_TERM1_D_HI. SPI TERM1 high gate voltage. Less than 17 volts means open.	8-bit unsigned integer
H+39	CH_ADC0_nTERM2_D_LO. SPI nTERM2 low gate voltage. Less than 9 volts means open.	8-bit unsigned integer
H+40	CH_ADC0_TERM2_D_LO. SPI TERM2 low gate voltage. Less than 9 volts means open.	8-bit unsigned integer
H+41	CH_ADC0_VCCWD. SPI Watchdog circuitry voltage. A volt means the Watchdog circuit is powered.	8-bit unsigned integer
H+42	CH_ADC0_VCCWDXCVR. SPI Watchdog external health receiver voltage. About 17 volts means powered.	8-bit unsigned integer
H+43	CH_ADC0_UMB_SAFE_B. SPI UMB SAFE B voltage. This is always zero.	8-bit unsigned integer
H+44	CH_ADC0_UMB_SAFE_A. SPI UMB SAFE A voltage. This is always zero.	8-bit unsigned integer
H+45	CH_ADC1_nTERM1_LO. SPI nTERM1 low side voltage.	8-bit unsigned integer
H+46	CH_ADC1_TERM1_HI. SPI TERM1 high side voltage.	8-bit unsigned integer
H+47	CH_ADC1_VCC. SPI redundant VCC voltage.	8-bit unsigned integer
H+48	CH_ADC1_LODXCVR. SPI liftoff detector receiver voltage. About 17 volts means powered.	8-bit unsigned integer



BYTE OFFSET	DESCRIPTION	DATA TYPE
H+49	CH_ADC1_nTERM2_I. SPI nTERM2 current.	8-bit unsigned integer
H+50	CH_ADC1_TERM1_LO. SPI TERM1 low side voltage.	8-bit unsigned integer
H+51	CH_ADC1_TERM2_LO. SPI TERM2 low side voltage.	8-bit unsigned integer
H+52	CH_ADC1_TERM2_I. SPI TERM2 current.	8-bit unsigned integer
H+53	CH_ADC1_HW_3. I/O board revision bit 3. Greater than 1.8 means on.	8-bit unsigned integer
H+54	CH_ADC1_HW_2. I/O board revision bit 2. Greater than 1.8 means on.	8-bit unsigned integer
H+55	CH_ADC1_HW_1. I/O board revision bit 1. Greater than 1.8 means on.	8-bit unsigned integer
H+56	CH_ADC1_HW_0. I/O board revision bit 0. Greater than 1.8 means on.	8-bit unsigned integer
H+57	CH_ADC1_nTERM2_LO. SPI nTERM2 low side voltage.	8-bit unsigned integer
H+58	CH_ADC1_nTERM2_HI. SPI nTERM2 high side voltage.	8-bit unsigned integer
H+59	CH_ADC1_nTERM1_HI. SPI nTERM1 high side voltage.	8-bit unsigned integer
H+60	CH_ADC1_TERM2_HI. SPI TERM2 high side voltage.	8-bit unsigned integer
H+61	CH_MAX_CPU_TEMP. Zynq maximum CPU temperature since boot.	8-bit unsigned integer
H+62	CH_MAX_VCCINT*. Zynq maximum VCCINT since boot.	8-bit unsigned integer
H+63	CH_MAX_VCCAUX*. Zynq maximum VCCAUX since boot.	8-bit unsigned integer
H+64	CH_MAX_VCCBRAM*. Zynq maximum VCCBRAM since boot.	8-bit unsigned integer
H+65	CH_MIN_CPU_TEMP*. Zynq minimum CPU Temperature since boot.	8-bit unsigned integer
H+66	CH_MIN_VCCINT*. Zynq minimum VCCINT since boot.	8-bit unsigned integer
H+67	CH_MIN_VCCAUX*. Zynq minimum VCCAUX since boot.	8-bit unsigned integer
H+68	CH_MIN_VCCBRAM*. Zynq minimum VCCBRAM since boot.	8-bit unsigned integer
H+69	CH_MAX_VCCPINT*. Zynq maximum VCCPINT since boot.	8-bit unsigned integer
H+70	CH_MAX_VCCPAUX*. Zynq maximum VCCPAUX since boot.	8-bit unsigned integer
H+71	CH_MAX_VCCPDRO*. Zynq maximum VCCPDRO since boot.	8-bit unsigned integer



BYTE OFFSET	DESCRIPTION	DATA TYPE
H+72	CH_MIN_VCCPINT*. Zynq minimum VCCPINT since boot.	8-bit unsigned integer
H+73	CH_MIN_VCCPAUX*. Zynq minimum VCCPAUX since boot.	8-bit unsigned integer
H+74	CH_MIN_VCCPDRO*. Zynq minimum VCCPDRO since boot.	8-bit unsigned integer

Table 13: Telemetry Analog Housekeeping Message Format

* The maximum/minimum values are maintained by **Zynq XADC** and updated every read. Since values are read more often than reported, this may contain values that were not otherwise reported.

The following is an example of converting the **ADC channel raw** value (those with 8-bit data) to the actual value using a programming language. See: Table 14: ADC Conversion Values section for scale, voltage reference, and bias.

C++ programming language:

```
double_t convertRawToValue(const uint8_t raw, const double_t scale,
    const double_t v_ref, const double_t bias)
{
    return (raw * ((scale * v_ref) / 256.0)) + bias;
} // Function convertRawToValue.
```

Code Block 2: Converting ADC Channel Raw Value to Actual Value

Python programming language:

```
def convertRawToValue(raw, scale, vref, bias):
    return (raw * ((scale * vref) / 256.0)) + bias
# Function convertRawToValue.
```

Code Block 3: Converting ADC Channel Raw Value to Actual Value

10.7 ANALOG-TO-DIGITAL CONVERTER (ADC) CHANNELS

The following table lists **ADC** channels and their default **ADC** conversion values. The values include:

- Scale** – Unit conversion scale.
- V Ref** – Reference voltage of ADC channel.
- Bias** – Unit conversion bias.



ADC CONVERSION VALUES

NAME	DESCRIPTION	SCALE	V REF	BIAS
CH_VCCPINT	Zynq PS VCCPINT.	3.0	1.0	0.0
CH_VCCPAUX	Zynq PS VCCPAUX.	3.0	1.0	0.0
CH_VCCPDRO	Zynq PS VCCPDRO.	3.0	1.0	0.0
CH_CPU_TEMP	Zynq On-Chip Temperature.	503.975	1.0	-273.15
CH_VCCINT	Zynq FPGA VCCINT.	3.0	1.0	0.0
CH_VCCAUX	Zynq FPGA VCCAUX.	3.0	1.0	0.0
CH_MB_TEMP	Mainboard Temperature.	-219.058	1.0	189.24
CH_VBRAM	Zynq FPGA VBRAM.	3.0	1.0	0.0
CH_VCCTERM	Termination supply voltage.	41.3	1.0	0.0
CH_VCC1V35_VS	1.35 reference voltage.	2.7	1.0	0.0
CH_TERM1_I	Zynq TERM1 current.	5.5	1.0	0.0
CH_nTERM1_I	Zynq nTERM1 current.	5.5	1.0	0.0
CH_TERM1_HI	Zynq TERM1 high side voltage.	41.3	1.0	0.0
CH_TERM2_HI	Zynq TERM2 high side voltage.	41.3	1.0	0.0
CH_nTERM1_HI	Zynq nTERM1 high side voltage.	41.3	1.0	0.0
CH_nTERM2_HI	Zynq nTERM2 high side voltage.	41.3	1.0	0.0
CH_IO_TEMP	I/O board temperature.	-219.058	1.0	189.24
CH_VCC5V0_VS	5V input voltage.	10.1	1.0	0.0
CH_TERM2_I	Zynq TERM2 current.	5.5	1.0	0.0
CH_nTERM2_I	Zynq nTERM2 current.	5.5	1.0	0.0
CH_TERM1_LO	Zynq TERM1 low side voltage.	41.3	1.0	0.0
CH_TERM2_LO	Zynq TERM2 low side voltage.	41.3	1.0	0.0
CH_nTERM1_LO	Zynq nTERM1 low side voltage.	41.3	1.0	0.0
CH_nTERM2_LO	Zynq nTERM2 low side voltage.	41.3	1.0	0.0
CH_ADC0_TERM2_D_HI	SPI TERM2 HI gate voltage.	74.27	3.0	0.0



NAME	DESCRIPTION	SCALE	V REF	BIAS
CH_ADC0_TERM1_D_LO	SPI TERM1 LO gate voltage.	11.64	3.0	0.0
CH_ADC0_nTERM1_D_LO	SPI nTERM1 LO gate voltage.	11.64	3.0	0.0
CH_ADC0_nTERM2_D_HI	SPI nTERM2 HI gate voltage.	24.56	3.0	0.0
CH_ADC0_VCCTERM	SPI VCCTERM.	41.3	3.0	0.0
CH_ADC0_TERM1_I	SPI TERM1 current.	5.25	3.0	0.0
CH_ADC0_nTERM1_I	SPI nTERM1 current.	5.25	3.0	0.0
CH_ADC0_VCC	SPI primary VCC voltage.	21.15	3.0	0.0
CH_ADC0_nTERM1_D_HI	SPI nTERM1 high gate voltage.	24.56	3.0	0.0
CH_ADC0_TERM1_D_HI	SPI TERM1 high gate voltage.	74.27	3.0	0.0
CH_ADC0_nTERM2_D_LO	SPI nTERM2 low gate voltage.	11.64	3.0	0.0
CH_ADC0_TERM2_D_LO	SPI TERM2 low gate voltage.	11.64	3.0	0.0
CH_ADC0_VCCWD	SPI Watchdog circuitry voltage.	24.56	3.0	0.0
CH_ADC0_VCCWDXCVR	SPI Watchdog external health receiver voltage.	11.64	3.0	0.0
CH_ADC0_UMB_SAFE_B	SPI UMB SAFE B voltage.	21.15	3.0	0.0
CH_ADC0_UMB_SAFE_A	SPI UMB SAFE A voltage.	21.15	3.0	0.0
CH_ADC1_nTERM1_LO	SPI nTERM1 low side voltage.	41.3	3.0	0.0
CH_ADC1_TERM1_HI	SPI TERM1 high side voltage.	41.3	3.0	0.0
CH_ADC1_VCC	SPI redundant VCC voltage.	21.15	3.0	0.0
CH_ADC1_LODXCVR	SPI liftoff detector receiver voltage.	7.7	3.0	0.0
CH_ADC1_nTERM2_I	SPI nTERM2 current.	5.5	3.0	0.0
CH_ADC1_TERM1_LO	SPI TERM1 low side voltage.	41.3	3.0	0.0
CH_ADC1_TERM2_LO	SPI TERM2 low side voltage.	41.3	3.0	0.0
CH_ADC1_TERM2_I	SPI TERM2 current.	5.5	3.0	0.0
CH_ADC1_HW_3	I/O board revision bit 3.	1.0	3.0	0.0
CH_ADC1_HW_2	I/O board revision bit 2.	1.0	3.0	0.0
CH_ADC1_HW_1	I/O board revision bit 1.	1.0	3.0	0.0



NAME	DESCRIPTION	SCALE	V REF	BIAS
CH_ADC1_HW_0	I/O board revision bit 0.	1.0	3.0	0.0
CH_ADC1_nTERM2_LO	SPI nTERM2 low side voltage.	41.3	3.0	0.0
CH_ADC1_nTERM2_HI	SPI nTERM2 hi side voltage.	41.3	3.0	0.0
CH_ADC1_nTERM1_HI	SPI nTERM1 hi side voltage.	41.3	3.0	0.0
CH_ADC1_TERM2_HI	SPI TERM2 hi side voltage.	41.3	3.0	0.0
CH_MAX_CPU_TEMP	Zynq Maximum CPU Temperature Data.	503.975	1.0	-273.15
CH_MAX_VCCINT	Zynq Maximum VCCINT Data.	3.0	1.0	0.0
CH_MAX_VCCAUX	Zynq Maximum VCCAUX Data.	3.0	1.0	0.0
CH_MAX_VCCBRAM	Zynq Maximum VCCBRAM Data.	3.0	1.0	0.0
CH_MIN_CPU_TEMP	Zynq Minimum CPU Temperature Data.	503.975	1.0	-273.15
CH_MIN_VCCINT	Zynq Minimum VCCINT Data.	3.0	1.0	0.0
CH_MIN_VCCAUX	Zynq Minimum VCCAUX Data.	3.0	1.0	0.0
CH_MIN_VCCBRAM	Zynq Minimum VCCBRAM Data.	3.0	1.0	0.0
CH_MAX_VCCPINT	Zynq Maximum VCCPINT Data.	3.0	1.0	0.0
CH_MAX_VCCPAUX	Zynq Maximum VCCPAUX Data.	3.0	1.0	0.0
CH_MAX_VCCPDRO	Zynq Maximum VCCPDRO Data.	3.0	1.0	0.0
CH_MIN_VCCPINT	Zynq Minimum VCCPINT Data.	3.0	1.0	0.0
CH_MIN_VCCPAUX	Zynq Minimum VCCPAUX Data.	3.0	1.0	0.0
CH_MIN_VCCPDRO	Zynq Minimum VCCPDRO Data.	3.0	1.0	0.0

Table 14: ADC Conversion Values

10.8 TALKBACK CHANNELS

The following table lists **talkback channels** and **ADC channels** that each talkback corresponds to.

NAME	ADC CHANNEL	THRESHOLDING VS. MAX/MIN
TERM2_D_HI_TB	CH_ADC0_TERM2_D_HI	Closer to min = on
TERM1_D_LO_TB	CH_ADC0_TERM1_D_LO	Closer to max = on



NAME	ADC CHANNEL	THRESHOLDING VS. MAX/MIN
nTERM1_D_LO_TB	CH_ADC0_nTERM1_D_LO	Closer to max = on
nTERM2_D_HI_TB	CH_ADC0_nTERM2_D_HI	Closer to min = on
nTERM1_D_HI_TB	CH_ADC0_nTERM1_D_HI	Closer to min = on
TERM1_D_HI_TB	CH_ADC0_TERM1_D_HI	Closer to min = on
TERM2_D_LO_TB	CH_ADC0_TERM2_D_LO	Closer to max = on
nTERM2_D_LO_TB	CH_ADC0_nTERM2_D_LO	Closer to max = on
VCCWD_TB	CH_ADC0_VCCWD	Closer to max = on
VCCWDXCVR_TB	CH_ADC0_VCCWDXCVR	Closer to max = on
UMB_SAFE_B_TB	CH_ADC0_UMB_SAFE_B	Closer to max = on
UMB_SAFE_A_TB	CH_ADC0_UMB_SAFE_A	Closer to max = on
IO_CONFIG4_TB	CH_ADC1_HW_3	Closer to max = on
IO_CONFIG3_TB	CH_ADC1_HW_2	Closer to max = on
IO_CONFIG2_TB	CH_ADC1_HW_1	Closer to max = on
IO_CONFIG1_TB	CH_ADC1_HW_0	Closer to max = on

Table 15: Talkback Channels

10.9 REPORT MESSAGE

The **Report** message is used to send a report message over telemetry in **ASCII** human-readable format.

TELEMETRY REPORT MESSAGE FORMAT

BYTE OFFSET	DESCRIPTION	DATA TYPE
0	Telemetry message header; see Telemetry Message Header section.	H-byte byte array
H+0	<p>Report message in the following format: <[timestamp]> [[report code]] [report message]</p> <p>Example: <257.201> [1121] IAFTU Wrapper Version = v1.1 2020-06-01</p> <p>See Table 41: Report Message Categories for a list of report messages.</p>	M-byte ASCII

Table 16: Telemetry Report Message Format

11 COMMAND

This section covers commands issued by a ground station to the **IAFTU**. The **IAFTU** receives a command through an **RS-422 serial data interface** at **115200 baud**.

Message Format

The **User Command Message** consists of a value for commanding from a ground station.

Explanations for each column in the table are as follows:

- The **byte number** in the **Byte Offset** column is zero-based, and the most significant byte first.
- The **byte arrangement** in each data field is the most significant byte first.

USER COMMAND MESSAGE FORMAT

BYTE OFFSET	DESCRIPTION	DATA TYPE
0	Header is the same as the telemetry header; see the Telemetry Message Header section.	H-byte byte array
H+0	One of the user commands listed in User Commands section Table 18: List of User Commands.	8-bit unsigned integer

Table 17: User Command Message Format

WARNING:

When the ability to command the IAFTU via umbilical or other hardware connection from the ground support equipment to the unit is no longer available, but the vehicle has not left the pad, there is a potential safety risk in the inability to disable the IAFTU. The IAFTU has no mechanism to disable itself if the Ground Support Equipment (GSE) is inadvertently disconnected and lift off does not occur. A contingency plan is recommended. Umbilical Disarm can be used if the connection is still present.

⚠ WARNING:

The IAFTU will not accept user commands once liftoff is detected. Liftoff detection is performed by CASS based on the configured Mission Data Load (MDL). Each MDL can designate its own unique liftoff detection logic. The detection of liftoff is not under the control of the IAFTU hardware or software.

11.1 USER COMMANDS

The following table lists all possible commands the user could use to work with each **IAFTU**. The **precondition** column lists preconditions to be met for a command to be accepted and processed. The **Sagrad wrapper** will provide an **acknowledge message** to the user when a valid **user command** is received. The **wrapper** will also give the user a **success/failure message** indicating whether the requested command was completed. A user can verify these messages are received to confirm the **user command** was accepted.

LIST OF USER COMMANDS

VALUE	NAME	DESCRIPTION
0x11	Logic Enable	Enable the CASS flight rule processing.
0x22	Master Enable A	Power up the termination circuit via the enable line A (FPGA-SAFE-EN-A).
0x33	Master Enable B	Power up the termination circuit via the enable line B (FPGA-SAFE-EN-B).
0x44	Master Disable A	Power down the termination circuit via the disable line A (FPGA-SAFE-DIS-A).
0x55	Master Disable B	Power down the termination circuit via the disable line B (FPGA-SAFE-DIS-B).
0x66	Watchdog Enable A	Power up the Watchdog circuit via the enable line A (WD-EN-A).
0x77	Watchdog Enable B	Power up the Watchdog circuit via the enable line B (WD-EN-B).
0x88	IAFTU Safe	Put the IAFTU in the safe mode.
0xFF	Test Mode Enable	Enable the test mode.
0xEE	Watchdog Reset Stop	Stop the IAFTU program from continuing to reset the Watchdog (test mode only).
otherwise	N/A.	Unused.

Table 18: List of User Commands



The **Watchdog** is a circuit built into the **IAFTU** with two resets that must be received within **300ms** before the **failsafe action** will occur. The **Sagrad wrapper** controls these resets. Once the **Watchdog enable command** is sent for a specific **Watchdog**, the **Watchdog** can't be disabled without power cycling the **IAFTU**. Once the **Sagrad wrapper** successfully enables the **Watchdog**, the next occurrence of the message **5017** (see Table 42: Event Information Report Messages (5000-5999)) will verify that the **Watchdog** is enabled.

FLIGHT ENABLED mode is transitioned to once the user issues command (0x22 or 0x33) to enable the **termination circuit**.

11.2 OPERATION PROCEDURE

STARTUP OPERATION PROCEDURE

STEP	COMMAND VALUE	COMMAND NAME	PRECONDITION	VERIFICATION
1	0x11	Logic Enable	The IAFTU is healthy. The Wrapper is in the STANDBY state. The CASS Rule Engine is in the READY FOR RULE PROCESSING state.	Verify message 5400 is received in the console and verify the expected user command was received.
2	0x22	Master Enable A	The IAFTU is healthy. The Wrapper is in the STANDBY or FLIGHT ENABLED state. The CASS Rule Engine is in the RULE PROCESSING state. Meaning the 0x11 command must be issued first. The CASS Rule Engine is not recommending ARM or DESTRUCT.	Same as the above.
3	0x33	Master Enable B	Same as the above.	Same as the above.
4	0x66	Watchdog Enable A	The IAFTU is healthy. The termination circuit is enabled. Meaning the 0x22 or 0x33 command must be issued first. The Wrapper is in the FLIGHT-ENABLED state.	Same as the above.



STEP	COMMAND VALUE	COMMAND NAME	PRECONDITION	VERIFICATION
			The CASS Rule Engine is in the RULE PROCESSING state. Meaning the 0x11 command must be issued first. The CASS Rule Engine is not recommending ARM or DESTRUCT.	
5	0x77	Watchdog Enable B	Same as the above.	Same as the above.

Table 19: Startup Operation Procedure

11.3 HOLD OPERATION PROCEDURE

STEP	COMMAND VALUE	COMMAND NAME	PRECONDITION	VERIFICATION
1	0x44	Master Disable A	The IAFTU is healthy. The Wrapper is in the STANDBY or FLIGHT ENABLED state. The CASS Rule Engine is in the RULE PROCESSING state. Meaning the 0x11 command must be issued first. The CASS Rule Engine is not recommending ARM or DESTRUCT.	Verify message 5400 is received in the console and verify the expected user command was received.
2	0x55	Master Disable B	Same as the above.	Same as the above.

Table 20: Hold Operation Procedure

11.4 SAFE OPERATION PROCEDURE

STEP	COMMAND VALUE	COMMAND NAME	PRECONDITION	VERIFICATION
1	0x88	IAFTU Safe	The Wrapper is in the STANDBY or FLIGHT ENABLED state.	Verify message 5400 is received in the console and verify the expected user command was received.

Table 21: Safe Operation Procedure

11.5 TEST WATCHDOG

This procedure will allow the user to test the **Watchdog** function by intentionally stopping the **IAFTU** from continuing to reset the **Watchdog timer**. The **IAFTU** must enter **test mode** before logic is enabled. Normal



user commands can be used before liftoff detection for **system integration testing** while in **test mode**. The **test mode** differs from normal operation by not activating the **termination output circuits**.

11.6 TEST WATCHDOG PROCEDURE

STEP	COMMAND VALUE	COMMAND NAME
1	0xFF	Test Mode Enable
2	0xEE	Watchdog Reset Stop

Table 22: Test Watchdog Procedure

12 NAVIGATION SENSORS

This section describes data the **IAFTU** expects to receive from **navigation sensors**.

JAVAD GNSS GPS

JAVAD GNSS Receiver External Interface Specification (GREIS)

- <http://www.javad.com/jgnss/support/manuals.html>
- http://www.javad.com/downloads/javadgnss/manuals/GREIS/GREIS_Reference_Guide.pdf

12.1 IAFTU NECESSARY JAVAD MESSAGE TYPES

MESSAGE TYPE	FREQUENCY	USAGE
[rE] Reference Epoch	10 or 20 Hz	Time synchronization.
[rV] Receiver's Position and Velocity	10 or 20 Hz	Time synchronization and CASS.
[RE] Reply	On Request	Console output and downlink telemetry Print message.
[ER] Error	On Request	Console output and downlink telemetry Print message.

Table 23: IAFTU Necessary JAVAD Message Types

Explanations for each column in the subsections are as follows:

- The byte number in the **Byte Offset** column is zero-based, the most significant byte.
- The bit number in the **Byte Offset** column is zero-based, and the least significant bit first.
- The byte arrangement in each data field is the least significant byte first.



- The 32-bit floating point in the **Data Type** column is the **IEEE 754 single precision floating point**. The 64-bit floating point in the **Data Type** column is the **IEEE 754 double precision floating point**.

Sensors configured to provide navigation information to an **IAFTU** may require certification for this purpose using **RCC 324** or similar.

The maximum buffer size, including header, is **1024 bytes** in each **navigation sensor input**.

At least one **Javad receiver** must be running at **20 Hz**, while the other receiver can be either **10** or **20 Hz**. The **IAFTU** requires at least one **20 Hz receiver** to be able to keep up with **CASS**. Other equipment besides a receiver can supply these messages to test the **IAFTU**; however, ranges normally require testing with the actual receivers.

The **IAFTU** will ignore any messages other than the ones listed above.

12.2 JAVAD HEADER MESSAGE FORMAT

BYTE OFFSET	DESCRIPTION	DATA TYPE
0	Identifier This field is used to identify the beginning of a message.	2-byte ASCII
2	Hexadecimal body length, [000...FFF]. This field determines the number of bytes in the body message.	3-byte ASCII

Table 24: JAVAD Header Message Format

12.3 JAVAD [rE] MESSAGE FORMAT

BYTE OFFSET	DESCRIPTION	DATA TYPE
0	Header: see JAVAD header message format section.	H-byte byte array
H+0	Sample number. This field determines whether this message's time information correlates with the time information found in other messages.	16-bit unsigned integer
H+2, bit 13	Time scale ID: 0 – GPS 1 – GLONASS 2 – UTC This field is used to determine the type of time in this message. Only GPS time is used. This message will not be processed if the type is not GPS time.	3-bit unsigned integer



BYTE OFFSET	DESCRIPTION	DATA TYPE
H+2, bit 11	Leap second status: 0 – no leap second epoch 1 – positive leap second 2 – negative leap second 3 – leap second status is unknown This field is not used	2-bit unsigned integer
H+2, bit 0	Week/day representation part of epoch representation: (a) if the time scale ID is GPS: week number [0...1023], 1024 indicates an unknown week number. (b) if the time scale ID is GLONASS: day number within a 4-year period [1...1461], 0 indicates an unknown day number (c) if the time scale ID is UTC: day number within the year [1...366], 0 indicates unknown day number. This field is used in time synchronous. This field will not be processed if the time scale ID is not GPS.	11-bit unsigned integer
H+4	Reference time. Milliseconds part of epoch representation [ms]: (a) if the time scale ID is GPS: milliseconds of GPS week; (b) if the time scale ID is GLONASS: milliseconds of GLONASS day; (c) if the time scale ID is UTC, milliseconds of UTC day; This field is used in time synchronous. This field will not be processed if the time scale ID is not GPS	32-bit unsigned integer
H+8	16-bit CRC This field is used to verify the integrity of this message.	16-bit unsigned integer

Table 25: JAVAD [rE] Message Format



12.4 JAVAD [rV] MESSAGE FORMAT

BYTE OFFSET	DESCRIPTION	DATA TYPE
0	Header: see JAVAD header message format section.	H-byte byte array
H+0	Sample number. This field determines whether this message's time information correlates with the time information found in the last [rE] message.	16-bit unsigned integer
H+2, bit 5	Difference between the raw measurement time (available from either [rM] or [rE] message) and the position time tag [-1024...1023], [5 ms]. This field with the time from the last [rE] message is used to populate the measurement_time and determine the gps_health.is_valid_GPS_time components in the CASS data structure.	11-bit signed integer
H+2, bit 0	Reserved This field is not used.	5-bit unsigned integer
H+4	32 MSB of Position X-component. This field populates the "pos_ECEF_X" variable in the CASS data structure.	32-bit unsigned integer
H+8, bit 24	8 LSB of Position ECEF X-component [10-4 m] or Latitude [10-11 radians] or Grid (Local) X-component [10-4 m]. This field populates the "pos_ECEF_X" variable in the CASS data structure.	8-bit unsigned integer
H+8, bit 23	1 - indicates that the Position is valid. This field determines the "gps_health.is_valid_GPS_data" variable in the CASS data structure.	1-bit flag
H+8, bit 21	0 – Position is given in the ECEF system. 1 – Position is given in geodetic coordinates (latitude, longitude, height above ellipsoid). 2 – Position is given in grid (or local) coordinates. 3 – Reserved. This field determines the type of positional information in this message. Only the ECEF system is used.	2-bit unsigned integer
H+8, bit 16	Number of GPS SVs used in computation. This field populates the 'gps_health.n_satellites' variable in the CASS data structure.	5-bit unsigned integer



BYTE OFFSET	DESCRIPTION	DATA TYPE
H+8, bit 15	1 - indicates that Velocity is valid. This field determines the “gps_health.is_valid_GPS_data” variable in the CASS data structure.	1-bit flag
H+8, bit 13	Reserved. This field is not used.	2-bit unsigned integer
H+8, bit 8	Number of GLONASS SVs used in computation. This field is not used.	5-bit unsigned integer
H+8, bit 4	Position computation mode. This field is not used.	4-bit unsigned integer
H+8, bit 0	Velocity computation mode. This field is not used.	4-bit unsigned integer
H+12	32 MSB of Position Y-component. This field populates the “pos_ECEF_Y” variable in the CASS data structure.	32-bit unsigned integer
H+16, bit 24	8 LSB of Position ECEF Y-component [10-4 m] or Longitude [10-11 radians] or Grid (Local) Y-component [10-4 m]. This field populates the “pos_ECEF_Y” variable in the CASS data structure.	8-bit unsigned integer
H+16, bit 15	PDOP. x10. This field populates the “gps_health.PDOP” variable in the CASS data structure.	9-bit unsigned integer
H+16, bit 0	RMS velocity error [0.001 m/s]. This field is not used.	15-bit unsigned integer
H+20	32 MSB of position Z-component. This field populates the “pos_ECEF_Z” variable in the CASS data structure.	32-bit unsigned integer
H+24, bit 24	8 LSB of position ECEF Z-component or Height above ellipsoid or geoid11 [10-4 m]. This field populates the “pos_ECEF_Z” variable in the CASS data structure.	8-bit unsigned integer
H+24, bit 20	Reserved. This field is not used.	4-bit unsigned integer



BYTE OFFSET	DESCRIPTION	DATA TYPE
H+24, bit 0	RMS Position error [0.001 m]. This field is not used.	20-bit unsigned integer
H+28, bit 4	Velocity X-component [10 ⁻⁴ m/s] or East component, depends on H+8, bit 21. This field populates the “vel_ECEF_X” variable in the CASS data structure.	28-bit unsigned integer
H+28, bit 2	Reserved. This field is not used.	2-bit unsigned integer
H+28, bit 0	2 MSB of GREIS datum number. This field is not used.	2-bit unsigned integer
H+32, bit 4	Velocity Y-component [10 ⁻⁴ m/s] or North component, depends on H+8, bit 21. This field populates the “vel_ECEF_Y” variable in the CASS data structure.	28-bit unsigned integer
H+32, bit 0	Bits 7...4 of datum number. This field is not used.	4-bit unsigned integer
H+36, bit 4	Velocity Z-component [10 ⁻⁴ m/s] or Height component, depends on H+8, bit 21. This field populates the “vel_ECEF_Z” variable in the CASS data structure.	28-bit unsigned integer
H+36, bit 0	4 LSB of GREIS datum number. This field is not used.	4-bit unsigned integer
H+40	16-bit CRC This field is used to verify the integrity of this message.	16-bit unsigned integer

Table 26: JAVAD [rV] Message Format

12.5 JAVAD [RE] MESSAGE FORMAT

BYTE OFFSET	DESCRIPTION	DATA TYPE
0	Header: See Table 24: JAVAD Header Message Format section.	H-byte byte array
H+0	Reply message. This field is used for reporting in the downlink telemetry message.	M-byte ASCII

Table 27: JAVAD [RE] Message Format



12.6 JAVAD [ER] MESSAGE FORMAT

BYTE OFFSET	DESCRIPTION	DATA TYPE
0	Header: See Table 24: JAVAD Header Message Format section.	H-byte byte array
H+0	Error description. This field is used for reporting in the downlink telemetry message.	M-byte ASCII

Table 28: JAVAD [ER] Message Format

12.7 NOVATEL OEM6/7 SENSOR MESSAGES

Configuration for the **Novatel receiver** should follow the commands listed below:

Serial configuration

1. serialconfig comX 115200 n 8 1 n off (where X is whichever port is being used)
2. interfacemode comX none NovAtel on
3. log comX BESTXYZB ontime 0.05
4. log comX PSRDOP2B onchanged

Ethernet configuration

1. ipconfig etha static {IP address} {netmask} {gateway} (replace {}'s with valid variables)
2. interfacemode icomX none NovAtel on
3. log icomX BESTXYZB ontime 0.05
4. log icomX PSRDOP2B onchanged
5. comconfig icomX UDP:3001

Sensors configured to provide navigation information to an **IAFTU** may require certification for this purpose using **RCC 324** or similar.

OEM7 Commands and Logs Reference Manual:

- https://docs.novatel.com/OEM7/Content/PDFs/OEM7_Commands_Logs_Manual.pdf



12.8 NOVATEL MESSAGE IDS

MESSAGE TYPE	MESSAGE ID	USAGE
BESTXYZ	241	Best available cartesian position and velocity
PSRDOP2	1163	DOP values for the satellites used in the PSR solution

Table 29: NovAtel Message IDs

All data sent to or from the **OEM7** and **SMART2** receivers is ordered **least significant bit (LSB)** first (little-endian). The data messages sent from the **GPS** must be sent as **binary data**. The structure of all **OEM7** binary messages follows the general conventions here:

- Basic format of:
 - Header:** 3 Sync bytes plus 25 bytes of header information. The header length is variable, as fields may be appended in the future. Always check the header length.
 - Data:** The data size is variable, dependent upon the message type.
 - CRC:** 4 bytes.
- The 3 Sync bytes will always be:

NOVATEL SYNC BYTES

BYTE	HEX	DECIMAL
First	AA	170
Second	44	68
Third	12	18

Table 30: Novatel Sync Bytes

- The **CRC** is a **32-bit CRC** performed on all data, including the **header**.

Not all data sent from the **OEM7 GPS** is used by the **IAFTU**. The data that is not used shall be mentioned in the description of the **byte offset** in the following message structures. The **IAFTU** will not look for the unused data, but there will still be data at those **byte offsets** in the messages. The messages will be sent using the following structures, including the unused data, but the **IAFTU** will only read and access the necessary data it requires to perform.

The **ASCII** and **Binary OEM7** family and **SMART2** message formats all contain a **32-bit CRC** for data verification. This allows the user to ensure the data received (or transmitted) is valid with high certainty.



12.9 NOVATEL HEADER MESSAGE FORMAT

BYTE OFFSET	DESCRIPTION	DATA TYPE
0	Sync Byte: Hexadecimal 0xAA	8-bit unsigned integer
1	Sync Byte: Hexadecimal 0x44	8-bit unsigned integer
2	Sync Byte: Hexadecimal 0x12	8-bit unsigned integer
3	Length of the header	8-bit unsigned integer
4	Message ID number of the log (see Table 29: NovAtel Message IDs)	16-bit unsigned integer
6	Unused by the IAFTU. Message Type.	8-bit unsigned integer
7	Unused by the IAFTU. Port Address.	8-bit unsigned integer
8	Message Length. The length in bytes of the body of the message, not including the header or the CRC	16-bit unsigned integer
10	Unused by the IAFTU. Sequence.	16-bit unsigned integer
12	Unused by the IAFTU. Idle time.	8-bit unsigned integer
13	Time Status. Indicates the quality of the GPS reference time (see OEM7 Reference Manual Table 12: GPS Reference Time Status on page 52).	8-bit unsigned integer
14	GPS reference week number	16-bit unsigned integer
16	Milliseconds from the beginning of the GPS reference week	32-bit unsigned integer
20	Unused by the IAFTU. Receiver Status.	32-bit unsigned integer
24	Reserved for internal use	16-bit unsigned integer
26	Unused by the IAFTU. Receiver S/W Version.	16-bit unsigned integer

Table 31: NovAtel Header Message Format



12.10 NOVATEL BESTXYZ MESSAGE FORMAT

BINARY OFFSET	FIELD TYPE	DESCRIPTION	DATA TYPE
0	BESTXYZ header	Log header. See NovAtel BESTXYZ message format section.	H-byte byte array
H+0	P-sol status	Solution status: see OEM7 Reference Manual Table 91: Solution Status on page 552 .	32-bit unsigned integer
H+4	pos type	Unused by the IAFTU. Position type.	32-bit unsigned integer
H+8	P-X	Position X-coordinate (m)	64-bit floating point
H+16	P-Y	Position Y-coordinate (m)	64-bit floating point
H+24	P-Z	Position Z-coordinate (m)	64-bit floating point
H+32	P-X σ	Unused by the IAFTU. The standard deviation of Position X-coordinate (m)	32-bit floating point
H+36	P-Y σ	Unused by the IAFTU. The standard deviation of Position Y-coordinate (m)	32-bit floating point
H+40	P-Z σ	Unused by the IAFTU. The standard deviation of Position Z-coordinate (m)	32-bit floating point
H+44	V-sol status	Solution status: see OEM7 Reference Manual Table 91: Solution Status on page 552 .	32-bit unsigned integer
H+48	vel type	Unused by the IAFTU. Velocity type.	32-bit unsigned integer
H+52	V-X	Velocity vector along X-axis (m/s)	64-bit floating point
H+60	V-Y	Velocity vector along Y-axis (m/s)	64-bit floating point
H+68	V-Z	Velocity vector along the Z-axis (m/s)	64-bit floating point
H+76	V-X σ	Unused by the IAFTU. The standard deviation of the Velocity vector along the X-axis (m/s)	32-bit floating point
H+80	V-Y σ	Unused by the IAFTU. The standard deviation of the Velocity vector along the Y-axis (m/s)	32-bit floating point
H+84	V-Z σ	Unused by the IAFTU. The standard deviation of the Velocity vector along the Z-axis (m/s)	32-bit floating point
H+88	stn ID	Unused by the IAFTU. Base station identification	32-bit unsigned integer



BINARY OFFSET	FIELD TYPE	DESCRIPTION	DATA TYPE
H+92	V-latency	Unused by the IAFTU. A measure of the latency in the velocity time tag in seconds. It should be subtracted from the time to give improved results	32-bit floating point
H+96	diff_age	Unused by the IAFTU. Differential age in seconds	32-bit floating point
H+100	sol_age	Unused by the IAFTU. Solution age in seconds	32-bit floating point
H+104	#SVs	Number of satellites tracked	8-bit unsigned integer
H+105	#solnSVs	Number of satellites used in solution	8-bit unsigned integer
H+106	#ggL1	Unused by the IAFTU. Number of satellites with L1/E1/B1 signals used in solution	8-bit unsigned integer
H+107	#solnMultiSVs	Unused by the IAFTU. Number of satellites with multi-frequency signals used in solution	8-bit unsigned integer
H+108	Reserved		8-bit unsigned integer
H+109	ext sol stat	Unused by the IAFTU. Extended solution status.	8-bit unsigned integer
H+110	Galileo and BeiDou sig mask	Unused by the IAFTU. Galileo and BeiDou signals used mask.	8-bit unsigned integer
H+111	GPS and GLONASS sig mask	Unused by the IAFTU. GPS and GLONASS signals used mask.	8-bit unsigned integer
H+112	xxxx	32-bit CRC	32-bit unsigned integer

Table 32: Novatel Bestxyz Message Format



12.11 NOVATEL PSRDOP2 MESSAGE FORMAT

BINARY OFFSET	FIELD TYPE	DESCRIPTION	DATA TYPE
0	PSRDOP2 header	Log header. See NovAtel PSRDOP2 message format section.	H-byte byte array
H+0	GDOP	Unused by the IAFTU. Geometric dilution of precision - assumes the 3D position and receiver clock offset (all 4 parameters) are unknown	32-bit floating point
H+4	PDOP	Position dilution of precision - assumes 3D position is unknown and receiver clock offset is known	32-bit floating point
H+8	HDOP	Horizontal dilution of precision	32-bit floating point
H+12	VDOP	Vertical dilution of precision	32-bit floating point
H+16	#systems	Unused by the IAFTU. Number of systems	32-bit unsigned integer
H+20	system	Unused by the IAFTU.	32-bit unsigned integer
H+24	TDOP	Time dilution of precision	32-bit floating point
		Next satellite offset = H+20+(#systems x 8)	
H+20+ (#systems x 8)	xxxx	32-bit CRC	32-bit unsigned integer

Table 33: NovAtel PSRDOP2 Message Format



12.12 BAE NAVSTRIKE 3.7 & M-CODE

IAFTU NECESSARY NAVSTRIKE MESSAGE TYPES

MESSAGE TYPE	SHCI Message ID	FREQUENCY	USAGE
GM-6	7106 (0x1BC2)	10 - 25 Hz	GPS Foreground Navigation Output
GM-8	7108 (0x1BC4)	1 Hz	GPS Background Navigation Data Output 1 (ECEF)

Table 34: IAFTU Necessary Navstrike Message Types

The maximum buffer size, including **header**, is **1024 bytes** in each navigation sensor input.

At least one **Navstrike receiver** must be running at **20 Hz**, normally achieved in **INS-aided mode**, while the other receiver can be either **10** or **20 Hz**. The **IAFTU** requires at least one **20 Hz** receiver to be able to keep up with **CASS**. Other equipment besides a receiver can supply these messages to test the **IAFTU**; however, ranges normally require testing with the actual receivers.

The **IAFTU** will ignore any messages other than the ones listed above.

A message consists of multiple 16-bit words. Each message contains a header portion of exactly 5 words, followed by a variable length data portion. A valid message will contain at least 5 words and no more than 38 words.

HEADER AND MESSAGE FORMAT

SECTION	WORD	DATA TYPE	DESCRIPTION
Header Portion	1	16-bit unsigned integer	Start of Message (0x81FF)
	2	16-bit unsigned integer	SHCI Message ID
	3	16-bit unsigned integer	Data Word Count
	4	16-bit unsigned integer	Protocol Flags
	5	16-bit unsigned integer	Header Checksum
Optional Data Portion	6	*	Start of Data
	...	*	...
	Word Count + 5	*	End of Data
	Word Count + 6	16-bit unsigned integer	Data Checksum

Table 35: Header And Message Format



GM-6 GPS FOREGROUND NAVIGATION OUTPUT MESSAGE FORMAT

WORD NUMBER	FIELD TYPE	DATA TYPE
1	Time of Validity	16-bit unsigned integer
2	Time of Transmission	16-bit unsigned integer
3, bit 0-11	Spare	
3, bit 12	Nav Constellation Status	0 = Y-code only-Receiver will use only Y-code satellites. Satellites producing P-code will be dropped. 1 = Mixed mode-Receiver will use either Y-code or P-code satellites (e.g. simulators)
3, bit 13	Validity	1 = Nav Data Valid
3, bit 14-15	Reserved	
4	GPS Altitude	16-bit, 2's Complement.
5-6	GPS Latitude	32-bit, 2's Complement.
7-8	GPS Longitude	32-bit, 2's Complement.
9	GPS Altitude	16-bit, 2's Complement.
10-11	GPS Velocity East	32-bit, 2's Complement.
12-13	GPS Velocity North	32-bit, 2's Complement.
14-15	GPS Velocity Up	32-bit, 2's Complement.
16-18	GPS System Time	48-bit CAPS EPFP floating-point
19	Delta T	16-bit, 2's Complement.
20	Estimated Horizontal Error	16-bit, 2's Complement.
21	Estimated Vertical Error	16-bit, 2's Complement.

Table 36: Gm-6 Gps Foreground Navigation Output Message Format



GM-8 GPS BACKGROUND NAVIGATION DATA OUTPUT 1 (ECEF) MESSAGE FORMAT

WORD NUMBER	FIELD TYPE	DATA TYPE
1, bit 0	Sentinel Bit	Set to 0
1, bit 1-2	GPS Filter Mode	00 = PVA, 01 = INS 10 = DRS, 11 = Not Used
1, bit 3	Lever Arm Correction	1 = Lever Arm Correction is used
1, bit 4	Clock Cal Time Stamp Select	1 = Time Stamp used for acquisition
1, bit 5	Reserved	
1, bit 6	Almanac Request	1 = Need Almanac Data
1, bit 7	UTC Valid	1 = UTC Valid 0 = GPS Time modulo 86,400 in words 19-20
1, bit 8-9	Reserved	
1, bit 10	Init Data Request	1 = Needs Init Data
1, bit 11	Reserved	
1, bit 12	BIT Not in Progress	1 = BIT Not in Progress
1, bit 13-14	Actual Receiver Mode	00 = TEST, 01 = INIT 10 = TRK, 11 = Not Used
1, bit 15	Nav Data Validity	1 = Nav Data Valid
2	Time of Validity	16-bit unsigned integer
3-4	ECEF Position X	32-bit, 2's Complement.
5-6	ECEF Position Y	32-bit, 2's Complement.
7-8	ECEF Position Z	32-bit, 2's Complement.
9-10	ECEF Velocity X	32-bit, 2's Complement.
11-12	ECEF Velocity Y	32-bit, 2's Complement.
13-14	ECEF Velocity Z	32-bit, 2's Complement.
15, bit 0-3	FOM	4-bit unsigned integer
15, bit 4-8	Reserved	
15, bit 9	Battery Fail	1 = Fail



WORD NUMBER	FIELD TYPE	DATA TYPE
15, bit 10	Reserved	
15, bit 11	RPU Fail	1 = Fail
15, bit 12	GPS Data Not Valid	1 = Not Valid
15, bit 13	Incorporating < 4 Meas.	1 = < 4 satellites are being utilized in nav solution
15, bit 14	State 3 Operation	1 = State 3, must have 1 or more satellites in state 3 operation
15, bit 15	State 5 Operation	1 = State 5, must have at least 4 satellites in state 5 operation
16	Est Horizontal Pos Error	16-bit, 2's Complement.
17	Est Vertical Pos Error	16-bit, 2's Complement.
18, bit 0	Reserved	
18, bit 1-4	Spare	
18, bit 5-8	No. Nav Channels in State 3	4-bit unsigned integer
18, bit 9	Commanded Constellation Type	0 = All Y-code SV constellation commanded 1 = Mixed Mode SV constellation commanded
18, bit 10-11	Reserved	
18, bit 12-15	No. Nav Channels in State 5	4-bit unsigned integer
19-20	UTC Measurement Time	32-bit, 2's Complement.
21	Altitude Difference	16-bit, 2's Complement.
22, bit 0-6	Number of Days CVds are Available	7-bit unsigned integer.
22, bit 7	Receiver Contains Keys	1 = Key entry successful or keys have not successfully zeroized
22, bit 8	Erase Failure	1 = Fail
22, bit 9	Insufficient Keys	1 = Insufficient amount of keys loaded.
22, bit 10	2 Hour Alert	1 = 2 hours or less before current key is expired
22, bit 11	GUV User	1 = Receiver contains GUV



WORD NUMBER	FIELD TYPE	DATA TYPE
22, bit 12	Key Failed Parity or Invalid Key	1 = Any key entered contains a parity error.
22, bit 13	Daily Key in Use (Incorrect)	1 = GUV User - The issue number is invalid. The receiver does not contain a key for the current day. 0 = GUV User - Set when a valid GUV (based on the receiver's current time) is entered.
22, bit 14	Daily Key in Use (Unverified)	1 = GUV User - The receiver is waiting for subframe data and does not contain a key for the current day. 0 = GUV User - Key for the current day has been obtained or the GUV issue number is invalid or expired.
22, bit 15	Daily Key in Use (Verified)	1 = CVw/CVm User - Key for the current day is in use. GUV User - Key for the current day has been obtained from the SV subframe data and is in use. 0 = CVw/CVm/GUV User - The receiver does not contain a key for the current day.
23-24	Reserved	
25, bit 0-8	Spare	
25, bit 9-12	Reserved	
25, bit 13	Battery Fail	1 = Fail
25, bit 14	Reserved	
25, bit 15	RPU Fail	1 = Fail
26	Lever Arm Used X	16-bit, 2's Complement.
27	Lever Arm Used Y	16-bit, 2's Complement.
28	Lever Arm Used Z	16-bit, 2's Complement.
29, bit 0-8	Reference Datum	9-bit, 2's Complement.
29, bit 9	Authenticated	1 = Authenticated
29, bit 10	Iono Parameters Available	1 = Iono Parameters Available



WORD NUMBER	FIELD TYPE	DATA TYPE
29, bit 11	Spare	
29, bit 12	Input Time Tag Mode	0 = Free Running 1 = Synchronize
29, bit 13-14	Commanded Receiver Mode	00 = TEST, 10 = TRK 01 = INIT, 11 = Not Used
29, bit 15	Nav Constellation Status	0 = Y-code only-receiver pseudorange and deltarange measurements used for nav solution are sourced only from Y-code SV tracking. 1 = mixed C/A, P, and/or Y
30	Recoverable Mission Duration	16-bit unsigned integer
31	Non-Recoverable Mission Duration Non-Recoverable MDZ Status	16-bit unsigned integer
32, bit 0-1	Non-Recoverable MDZ Status	00 = NRMDZ Not Set, 01 = NRMDZ Loaded/ Not Set, 10 = NRMDZ Set, 11 = Reserved
32, bit 2-3	Recoverable MDZ Status	00 = RMDZ Not Set, 01 = RMDZ Loaded/ Not Set, 10 = RMDZ Set, 11 = Reserved
32, bit 4-5	KDP IP Zeroization Status	00 = Zeroize attempted and Completed, 01 = Zeroize attempted and Failed, 10 = Never attempted, 11 = Reserved
32, bit 6-7	KDP CV Zeroization Status	00 = Zeroize attempted and Completed, 01 = Zeroize attempted and Failed, 10 = Never attempted, 11 = Reserved
32, bit 8-9	KDP Status	00 = KDP Operational, 01 = KDP Failure, 10 = KDP Uninitialized, 11 = Reserved
32, bit 10-11	SAASM Lock Status	00 = Receiver Unlocked,



WORD NUMBER	FIELD TYPE	DATA TYPE
		01 = Receiver Locked, 10 = Unlock Failed, 11 = Not Used
32, bit 12-13	SAASM Memory Status	00 = SAASM Not Zeroized, 01 = SAASM Zeroized, 10 = Zeroize Failed, 11 = Not Used
32, bit 14-15	OTAR Status	00 = No OTAR Entry, 01 = OTAR Entry Successful, 10 = OTAR Entry Fail, 11 = Not Used

Table 37: Gm-8 GPS Background Navigation Data Output 1 (Ecef) Message Format

13 IAFTU BOOT SEQUENCE AND POWER ON SELF-TEST

Bootup: The software loaded in the **IAFTU flash memory** consists of a single flash image with the following partitions:

1. **Zynq configuration** and customized **First Stage Boot Loader (FSBL)**
2. **First Stage Boot Loader (FSBL)**
3. **First Stage Boot Loader (FSBL) (U-boot)**
4. **First Stage Boot Loader (FSBL) (VxWorks + Wrapper + CASS)**

At Bootup, either the **First Stage Boot Loader (FSBL)** (default) or the **Maintenance program** (press 'm') may be selected. The unit must be power cycled to exit one and start the other.

Connecting to the **IAFTU Console serial port** before power-up is best to see all the messages. The **baud rate** is **1152000**.

First Stage Boot Loader: When the unit initializes, it will show the first stage boot loader information.

NOTE:

Version may vary depending on IAFTU load.

NIAFTU First Stage Boot Loader v2.1 2020-12-18 (based on Xilinx 2019.1)

Maintenance Mode: If 'm' is pressed any time before the following prompt, "Press one of the following keys," times out (~10s), the **IAFTU** will boot into **maintenance mode (U-boot)**, and the following will be displayed. This mode is only used to update **Flash**.

Press one of the following keys:

- 'o' for flight mode
- 'q' for flight mode without memory test
- 'm' for maintenance mode
- 's' for maintenance mode without memory test
- 'r' for recovery mode

any other or no key is the same as 'o' key.



Memory Test: The following will be displayed within the Boot sequence, indicating the **DDR** memory is being tested. The **IAFTU** will halt if the memory test fails and must be power cycled to reset.

Testing 511 MB of DDR:

- *Incrementing Value Test PASSED*
- *Walking Ones Test PASSED*
- *Walking Zero's Test PASSED*
- *Inverse Address Test PASSED*
- *Fixed Pattern Test PASSED*

Partition Loading: Following the **Maintenance** sequence, **memory** partitions are checked, with the following being displayed during the sequence. Each partition is checked and loaded.

- *Silicon Version 3.1*
- *Boot mode is NAND*
- *Reading boot image partitions*
- *Partition Number: 1*
- *Bitstream*
- *Actual checksum*
- *6F67EFC82C27CDADD115F721C9BAA71F*
- *Calculated checksum*
- *6F67EFC82C27CDADD115F721C9BAA71F*

-
- *FPGA Done !*
 - *Time taken is 0.055981 seconds*
 - *TERM/NTERM pattern registers to default*
 - *Filling ECC region starting at 0x80080000 with init pattern*

.....

.....

.....

.....

.....

.....

.....



- Done
- Partition Number: 2
- Skipping partition 2
- Partition Number: 3
- Application
- Load Addr = 0x80200000
- Exec Addr = 0x80200000
- Actual checksum
- 7E6ABA49F9ECF404915DACF539486A80
- Calculated checksum
- 7E6ABA49F9ECF404915DACF539486A80
- Handoff Address: 0x80200000
- Total Execution time is 164.354344 seconds ^M
- Reading environment from 0x02000000
- IAFTU=SN0049
- bootargs=gem(0,0)host:NIAFTU_flight.elf h=192.168.63.198 e=192.168.63.75:ffffff00
g=192.168.63.1 f=0x80 tn=SN0049 o=0,0x2400000,3,0
- ethaddr=00:22:88:01:78:20

VxWorks: Unless the maintenance image is chosen, control is transferred to the **VxWorks**, and the following will be displayed. In which the **IAFTU** will then begin with its bootup.

SUCCESSFUL_HANDOFF

- FSBL Status = 0x1
- User: target
- gem0: using MAC address 00:22:88:01:78:20
- Adding 9061 symbols for standalone.
- About to call taskCreate IAFTU
- inside of usrRptAppInit



AFTS States: There are seven distinct states the **IAFTU** can be in at any given time. These states are listed and explained below.

State 0 - Stop processing: The **IAFTU** transitions to the stop processing state if initialization encounters an error.

State 1 - Boot: When the **IAFTU** is initially powered on, it enters the boot state. Neither **VxWorks** nor the wrapper are running yet. The unit conducts self-tests.

State 2 - Initialization: When the **Wrapper** starts, it begins in initialization. The boot-up process must be completed, and the console command must be sent to start the Wrapper.

State 3 - Stand by: The standby state is transitioned to after initialization. In this state, the wrapper waits for valid sensor data and processes sensor data. This is also when **CASS** will go from the disabled state to the enabled state.

State 4 - Flight enabled: The **IAFTU** will transition into the flight-enabled state after standby. In this state, the termination circuits are enabled and powered. This is the only processing state which performs the safety function. This state must be entered before the first motion of the vehicle. Liftoff detections are processed in this state. Recommendations from the **CASS Rule Engine** are processed in this state.

State 5 - End of mission: The **Wrapper** transitions to the end of mission state from standby or flight-enabled state. This terminal state is entered when the **IAFTU** function is no longer required. Recommendations from the **CASS Rule Engine** are not processed in this state. The **CASS Rule Engine** is disabled in this state.

State 6 - Flight termination: The **Wrapper** transitions to the flight termination state from the flight enabled state when it meets the termination conditions. In this state, the powered flight must end. This is a terminal state that repeatedly sends commands to end powered flight.

nTermination Activation: It is important to note that the **nTERM** ports are activated in multiple cases, as seen below:

- CASS recommends termination.
- CASS transitions to End-of-Mission state.
- IAFTU becomes unhealthy.



14 CBIT OPERATION

IAFTU MEMORY

IAFTU NAND Organization: The IAFTU organizes its NAND by predefined **byte/block** offsets. These offsets have been calculated to allow for **50%** bad blocks vs. the expected maximum size. Only the maintenance image and the **FSBL** will have the library code to write/erase arbitrary flash blocks; the **Flight Software NAND** driver is constrained to write to its region.

- NAND flash ECC on read/write with bad block table.
- Zynq Proxy ECC for RAM (uses both CPU and FPGA).

14.1 IAFTU NAND BYTE/BLOCK OFFSETS

BLOCK OFFSET	BYTE START	SIZE (BYTES)	USAGE
0	0x0	0x01000000	Boot Image Block
32	0x01000000	0x01000000	Rescue Boot Image Block
64	0x02000000	0x00200000	Sysconfig Data
68	0x02200000	0x00200000	Sysconfig Backup
72	0x02400000	0x00200000	IAFTU Config 0
76	0x02600000	0x00200000	IAFTU Config 1
80	0x02800000	0x00200000	IAFTU Config 2
84	0x02A00000	0x00200000	IAFTU Config 3
88	0x02C00000	0x00200000	IAFTU Config 4
92-96		0x00200000	Gap
96-2031	0x03000000 - 0x3F87FFFF		Flight Software Write Area ~1000 MB
2032-2047	0x3F880000 - 0x3FFFFFFF		Bad Block Table And Other

Table 38: IAFTU NAND Byte/Block Offsets



Of these values, only the sysconfig data and backup have hardcoded offsets (bad blocks automatically skipped). The other areas are somewhat flexible in location as long as they do not overlap.

- **boot image block:** sequential search starting at block 0 for a valid blob by the **Zynq** firmware.
- **rescue boot image block:** sequential search starting after boot image blob for a valid blob by the Zynq firmware.
- **IAFTU configs:** byte offset specified at **Afss** application startup.
- **Flight Software Write area:** region allowed specified in mission **SDL** file.

The memory test that **CBIT** runs is for **ECC**. This test checks for any uncorrectable **ECC** errors reported by the hardware and can result in an unhealthy **IAFTU**.

Other CBIT Functions

CBIT run multiple tests to check the health of the software and hardware every second (except in **STOP PROCESSING** state). The list of all the tests run by **CBIT** are listed below:

- Check whether the power to the system is good by checking whether the **VCC** is within the operational limits; see section Error: Reference source not found.
- Check whether the power to the liftoff detection transceiver is good by checking whether the **VCCLODXCVR** is within the operational limits.
- Check whether the power to the **Watchdog** circuit is good by checking whether the **VCCWD** is within the operational limits.
- Check whether the power to the Watchdog transceiver is good by checking whether the **VCCWDXCVR** is within the operational limits.
- Check for any uncorrectable **ECC** errors.
- Ensure that the system clock rate is not changed.
- Ensure that the states of **Wrapper**, **CASS**, and termination circuitry agree with each other; see the following table.



15 SYSCONFIG DATA

This section stores configuration data used by the **Maintenance Mode** image and the Flight Software. This data is stored in **NAND** by the **Maintenance Mode saveenv** command and consists of a **32-bit CRC** followed by a series of zero-terminated strings in alphabetical order (case-sensitive) in the format of "name=value."

If the 'o' field contains valid **startAfss** options, then the application task will automatically start with those options.

15.1 SYSTEM CONFIGURATION (SYSCONFIG) DATA FORMAT

NAME	FORMAT	USE	EXAMPLE
IAFTU	Up to 8 ASCII characters	Printed by images to identify the IAFTU.	SN0005
bootargs	VxWorks Boot Line (up to 256 chars)	Sets the network information for the IAFTU flight software (other values are not used) h=Host Computer IP e=NIAFTU IP Address:Net Mask g=Gateway IP address f=0x80 tn=IAFTU Serial Number o=Afss autostart options	gem(0,0)host:NIAFTU_flight.e lf h=192.168.63.198 e=192.168.63.75:ffffff00 g=192.168.63.1 f=0x80 tn=SN0049 o=0,0x2400000,0,0
ethaddr	MAC Address	Sets the MAC address of the IAFTU gem ethernet controller	00:22:88:01:77:c7
ipaddr	IP Address	Sets the IP address used only by Maintenance Mode. It does not have to be the same as the bootargs value.	192.168.63.13
serial#	Up to 8 ASCII characters	Set by the factory to identify the mainboard serial number	17260013
serverip	IP Address	Sets the IP address of the configuration server used only by Maintenance Mode	192.168.63.198

Table 39: System Configuration (Sysconfig) Data Format

NOTE:

- If this data is missing, the IAFTU will still boot into **Flight Software** or **Maintenance Mode**, but the networking information will have to be manually configured using the serial console.
- The recovery block has a duplicate of the **Sysconfig** data that can only be used by the Maintenance Mode image.

IAFTU Configuration: An IAFTU configuration file is the **MDL** – Mission Data Load (mission rules file).

The IAFTU stores this file as a stream of **ASCII** bytes, each prefixed with the byte length.

15.2 FLIGHT CONFIGURATION DATA FORMAT

BYTE OFFSET	SIZE	VALUE	DESCRIPTION
	4 bytes	MDL Length (binary, little endian)	Number of bytes in the MDL
	8 bytes	ASCII bytes	CASS Mission Data Load file

Table 40: Flight Configuration Data Format

Bad Block Table: A **Bad Block Table** is created and updated by the **Xilinx nandps library** code linked into the **FSBL**, **VxWorks**, and **maintenance** images. The format and functionality are maintained as long as all reads/writes/updates use this library.



16 INSTALLING CONFIGURATION FILE

LOAD MDL

1. Power the unit and enter **Maintenance** mode.
2. First, load the file into **DDR** memory.

```
tftpboot {ddr_memory_location} {foo.ext}
```

Example: tftpboot 0x10000000 foo.dat.

NOTE:

The configuration file can also be loaded over RS-422 using:

```
"loady memory_location_in_DRR baud_rate"
```

Do not use 0xmemory_location.

Also, loadx or loadz will work. The unit will accept the data unit once a stopbit is sent. This will depend on the protocol an end-user is using on their serial terminal, xmon, ymon, or zmon.

3. Erase the location on the **NAND** memory you wish to use. Please keep in mind the memory map sent with your unit. That contains the **NAND** memory locations already in use and necessary for the unit's operation.

```
nand erase {memory_location_in_hex} {file_size_in_bytes_in_hex}
```

Example: NAND erase 0x02400000 0x451450.

4. Load the **MDL** into **NAND** memory

```
nand write 0x10000000 0x02400000 0x451450
```

5. Power cycle and verify **MDL** was loaded properly(optional)

```
nand read {ddr_memory_location} {memory_location_in_hex} {file_size_in_hex}
```

Example: nand read 0x10000000 0x02400000 0x451450.

```
md5sum {ddr_memory_location} {file_size_in_hex}
```

Example: md5sum 0x10000000 0x451450.

6. Power cycle and start the **afss** once the unit fully boots.

```
startAfss {afss_id},{internal_gps_config},{nand_offset_of_mdl}
```

Example: startAfss 0,0,0x02400000.

NOTE:

Upon a Power Cycle if U-boot boots into a 'dirty' mode the Flight Image has been lost. The IAFTU will then need to be sent back to the manufacturer for it to be fixed. (e.g., U-boot 2016.07-03719-gaebea9d-dirty)

Change Boot Configuration

1. Power unit and enter **Maintenance** mode.
2. Check the current environment variable saved to **NAND** memory and change the bootargs variable if needed.

```
printenv
```

3. Change the current bootargs environmental variable to desired.

```
set bootargs 'gem(0,0)host:NIAFTU_flight.elf h=192.168.63.198 e=192.168.63.13:ffffff00  
g=192.168.63.1 f=0x80 tn={serial_number} o={AFSSID}, {mdl_memory_location}, {gps_config},  
{telemetry_config}'
```

Example: set bootargs 'gem(0,0)host:NIAFTU_flight.elf h=192.168.63.198 e=192.168.63.75:ffffff00
g=192.168.63.1 f=0x80 tn=SN0049 o=0,0x2400000,0,0'.

4. The serial_number is the associated serial number tied to the **IAFTU** (e.g., SN0003).
5. The bootargs **gps_config** value is a number between **0** to **3**, inclusively, that determines the **GPS** being used and the connection to it as well. Each value represents a combination between the **GPS Javad** or **Novatel**, with the connection being Serial or Ethernet. The following values represent the combinations.

0 – Javad with Serial

1 – Javad with Ethernet

2 – Novatel with Serial

3 – Novatel with Ethernet



6. The bootargs **telemetry_config** value is one of two numbers, **0** or **1**. Each value represents the connection the **Telemetry** stream shall output to. The following values are defined as such:

0 – Ethernet Telemetry output

1 – Serial Telemetry output

7. When the environment variables are set, they must be saved to memory.

saveenv

8. Power cycle the **IAFTU** for the environment variables to be used.



17 INSTALLATION GUIDE

Storage: The IAF TU shall be stored in a temperature, humidity, and **ESD-controlled environment**, as defined by each user's launch range requirements; the **Sagrad SG901-1229** was manufactured and stored in compliance with NASA IAF TU Piece Parts Plan NIAFTU-010.

Temperature and humidity shall be always monitored, and **electrostatic discharge (ESD)** protocols shall be followed. Current conditions and violations will be monitored and recorded electronically when possible and by mechanical/manual means at other times. Parts will be stored in a secure area and/or device with anti-tamper tags or lockouts.

ESD control shall be in accordance with [MSFC-RQMT-2918](#). Moisture control will be done in compliance [J-STD-033](#). The temperature will be maintained at $21^{\circ}\text{C} \pm 10^{\circ}$ with a relative humidity between **30%** and **60%**.

Mounting: The IAF TU is intended to be mounted in an environmentally controlled portion of the launch vehicle, free of exposure to salt fog or fine sand debris (specific allowances may be provided by individual launch range/flight safety representatives). It shall be used according to operating temperature and humidity ranges specified in Section 1.0 of this document.

Cable Connection: Care should be taken when attaching the cables. **Mating cable** connectors and their associated **IAFTU connectors** are keyed to eliminate the possibility of mismatched cable mating. When mating the connectors, slightly turn the mating connector while gently pressing down on top of the connector housing until the connector seats. All connectors should be hand-tightened until the red ring on the **IAFTU connector** cannot be seen when viewing from the side. A rubber strip tool is available from Glenair to assist in installing and removing connectors if desired. When attaching cables, it is generally easier to start by mounting connectors in the following order:

NOTE:

- Refer to [Glenair Mighty Mouse connector](#) information for additional connector specifications and mating instructions.
- Unused connectors on the IAF TU should be covered with applicable Glenair connector covers.

18 HELPFUL OPERATIONAL HINTS

1. Check all connections and ensure no loose cable connectors before proceeding.
2. Commands are case-sensitive!
3. On initial turn ON, the IAFTU should draw ~0.2A at 28V (with an internal GPS present).
4. Make sure the terminal keyboard CAPS lock is not on.
5. When connecting through the serial "console," ensure that the TX and RX are connected to the appropriate mating communication lines. Check the polarity of the TX and RX, as well as the +/- lines, if not communicating. ("sniffer" on a 3rd computer is useful).
6. Serial connection speed should be set to 115200.
7. As described in **IAFTU Boot Sequence and Power-on Self-Test**, there are two modes you can enter by pressing the following keys on power up.
 - a) 'o' - flight mode (is defaulted to if no key is pressed)
 - b) 'm' - maintenance (U-boot)

NOTE:

The following two modes, and key entries, shall not be used during Flight processes ('s' – skip and 'q' – quick).

- c) 's' - skip (skips memory test to maintenance, U-boot)
- d) 'q' - quick (skips Memory test to flight mode, VxWorks)
- e) 'r' - recovery mode



8. For U-boot, the following commands may be helpful.

(See [U-boot manual](#), available online, for further command information.)

- a) '**printenv**' shows information saved to **NAND** memory.
- b) '**saveenv**' must be entered after making changes.
- c) '**set ipaddr**' sets the IP address.
- d) '**set serverip**' sets the server IP address for **tftp** boot and various functions.
- e) '**help**' shows help commands.



19 REPORT MESSAGES

19.1 REPORT MESSAGE CATEGORIES

The report messages are categorized by their severity as follows:

SEVERITY LEVEL	ABBREVIATION	CODE RANGE
Information (CASS)	INF	0 – 99
Low (CASS)	LOW	100 – 299
Moderate (CASS) (unused)	MOD	200 – 299
Medium (CASS)	MED	300 – 399
Serious (CASS)	SER	400 – 499
Severe (CASS)	SEV	500 – 999
Event Information	EVENT	5000 – 5999
Initialization Information	INIT	6000 – 6999
Recoverable Errors	ERROR	7000 – 7999
Fatal Errors	FATAL	8000 – 8999

Table 41: Report Message Categories

A list of CASS report messages (0 thru 999) can be found in the **CASS distribution** package, **CASS_FlightCode_SRS_2015April21.xlsx**, **CASS Error Definition** worksheet. A brief description of each category for report messages is as follows:

- CASS INF. Informational message only. No negative effect.
- CASS LOW. Trivial error. Reported but ignored. Full functionality retained.
- CASS MED. Some loss of functionality. Continuing with degraded performance.
- CASS SER. Loss of functionality. External software must act to recover from the error state.
- CASS SEV. Unrecoverable error.
- REPORT EVENT. Event information. No negative effect.
- REPORT INIT. Initialization information. No negative effect.
- REPORT ERROR. Some loss of functionality. Continuing with degraded performance.
- REPORT FATAL. Unrecoverable error.



Each reporting category is further broken down in the following by their code and class:

- #001 - #099: MainManager
- #100 - #119: Configuration
- #120 - #199: XilinxNAND
- #200 - #299: NavigationManager / NavigationTask
- #300 - #399: DecisionManager
- #400 - #499: UserCommand
- #500 - #599: TermCommand
- #600 - #619: XilinxGPIO
- #620 - #639: XilinxADC
- #640 - #699: XilinxSPI
- #700 - #719: TelemetryManager
- #720 - #739: TelemetryMessage
- #740 - #799: IAFTUReport
- #800 - #849: TimeManager
- #850 - #899: CpuStats
- #900 - #919: IAFTUString
- #920 - #939: DataManipulator
- #940 - #959: SerialInputOutput
- #960 - #999: UdpInputOutput

A list of **Wrapper report messages** (5000 thru 8999) is shown in the following subsections.

19.2 EVENT INFORMATION REPORT MESSAGES (5000-5999)

CODE	MESSAGE
5000	IAFTU state changed from [str] to [str].
5001	IAFTU state changed from [str] to [str].
5002	IAFTU state changed from [str] to [str].
5003	IAFTU state changed from [str] to [str].
5004	IAFTU test mode changed from [str] to [str].
5005	IAFTU test mode has been [str].
5006	IAFTU will stop resetting the watchdog.
5007	IAFTU has already stopped resetting the watchdog.



CODE	MESSAGE
5008	Start the main loop.
5009	Wait for a good system time before changing the IAFTU state to STANDBY.
5010	Sensor Counts (Name=Valid,Invalid): [str]=[num],[num] [str]=[num],[num] ...
5011	Telemetry: Generated=[num] Dropped=[num] Sent=[num] Failed=[num]
5012	User Command: Received=[num] Error=[num] Processed=[num]
5013	TI ADC 0 (channel=not received): 0=[num] 1=[num] 2=[num] 3=[num] 4=[num] 5=[num] 6=[num] 7=[num] 8=[num] 9=[num] 10=[num] 11=[num] 12=[num] 13=[num] 14=[num] 15=[num]
5014	TI ADC 1 (channel=not received): 0=[num] 1=[num] 2=[num] 3=[num] 4=[num] 5=[num] 6=[num] 7=[num] 8=[num] 9=[num] 10=[num] 11=[num] 12=[num] 13=[num] 14=[num] 15=[num]
5015	Idle CPU 0=[num]% 1=[num]%
5016	Log (category=count): Ifo=[num] Low=[num] Med=[num] Ser=[num] Sev=[num] Eve=[num] Ini=[num] Err=[num] Fal=[num]
5017	Power=[str] Liftoff XCVR=[str] IAFTU=[str] Health=[str] Watchdog=[str] Watchdog XCVR=[str]
5018	CASS=[str] Arm=[str] Destruct=[str]
5019	TERM=[str] TERM1=[str] TERM2=[str] NTERM1=[str] NTERM2=[str]
5020	Free Memory Bytes=[num] Blocks=[num] Max Block Size=[num]
5021	Allocated Memory Bytes=[num] Blocks=[num] Max Bytes=[num]
5022	Memory ECC Error Stats: Single-Bit=[num] Multi-Bit=[num]
5023	Voltage (Zynq Int ADC): VCCINT=[num] VCCAUX=[num] VBRAM=[num] VCCPINT=[num] VCCPAUX=[num] VCCPDRO=[num]
5024	Voltage (Zynq Ext ADC): VCCTERM=[num] VCC1V35-VS=[num] VCC5V0-VS=[num]
5025	Voltage (TI ADCs): VCCTERM(0)=[num] VCC(0)=[num] VCC-WD=[num] VCC-WDXCVR=[num] VCC(1)=[num] VCCLODXCVR=[num]
5026	Temperature (deg C): CPU=[num] Min CPU=[num] Max CPU=[num] Main Board=[num] IO Board=[num]
5027	System Clock Rate = [num]
5028	Time Re-Sync Count=[num] Time Jump Count=[num] Average Time Drift=[num]
5029	IAFTU state changed to STOP PROCESSING.
5220	GPS EVENT [str] for [str]: BIT POS [num] SET TO [num], [str].



CODE	MESSAGE
5221	GPS [str] COMP [num]: [str]
5222	GPS [str] [limit status]: [reading type] is [value] [unit].
5223	GPS [str]: PRN [num] CNO [num], PRN [num] CNO [num], ...
5224	GPS update CASS from Novatel
5300	Enabled CASS logic.
5301	CASS logic has been enabled.
5302	CASS logic has been disabled.
5303	Disabled CASS logic.
5400	Received user command (command=[NUM] time=[num] sec ID=[num]) [str].
5401	Processed user command ([num]).
5500	Wrote pattern [num] (ENABLE_A) to FPGA register at [num]; the previous pattern was [num].
5501	Wrote pattern [num] (ENABLE_B) to FPGA register at [num]; the previous pattern was [num].
5502	Wrote pattern [num] (SAFE_A) to FPGA register at [num]; the previous pattern was [num].
5503	Wrote pattern [num] (SAFE_B) to FPGA register at [num]; the previous pattern was [num].
5504	Wrote pattern [num] (unlatch ENABLE_A) to FPGA register at [num]; the previous pattern was [num].
5505	Wrote pattern [num] (unlatch ENABLE_B) to FPGA register at [num]; the previous pattern was [num].
5506	Wrote pattern [num] (unlatch SAFE_A) to FPGA register at [num]; the previous pattern was [num].
5507	Wrote pattern [num] (unlatch SAFE_B) to FPGA register at [num]; the previous pattern was [num].
5508	Wrote pattern [num] (WD_ENABLE_A) to FPGA register at [num]; the previous pattern was [num].
5509	Wrote pattern [num] (WD_ENABLE_B) to FPGA register at [num]; the previous pattern was [num].
5510	Wrote pattern [num] (TERM1_HI) to FPGA register at [num]; the previous pattern was [num].
5511	Wrote pattern [num] (TERM1_LO) to FPGA register at [num]; the previous pattern was [num].
5512	Wrote pattern [num] (TERM2_HI) to FPGA register at [num]; the previous pattern was [num].
5513	Wrote pattern [num] (TERM2_LO) to FPGA register at [num]; the previous pattern was [num].
5514	Wrote pattern [num] (NTERM1_HI) to FPGA register at [num]; the previous pattern was [num].
5515	Wrote pattern [num] (NTERM1_LO) to FPGA register at [num]; the previous pattern was [num].
5516	Wrote pattern [num] (NTERM2_HI) to FPGA register at [num]; the previous pattern was [num].



CODE	MESSAGE
5517	Wrote pattern [num] (NTERM2_LO) to FPGA register at [num]; the previous pattern was [num].
5800	Re-synced system time from [num] wk [num] ([num]) sec to [num] wk [num] ([num]) sec.
5801	Current Time [num] sec, Last Sync Time [num] sec, Time Delta [num] sec.

Table 42: Event Information Report Messages (5000-5999)

19.3 INITIALIZATION INFORMATION REPORT MESSAGES (6000 – 6999)

CODE	MESSAGE
6000	CPU = [str]
6001	Runtime = [str] [str]
6002	Kernel Version = [str]
6003	Board support package version = [str]
6004	IAFTU VxWorks Version = [str]
6005	IAFTU Wrapper Version = [str]
6006	Task Name=[str] Stack Size=[num] Priority=[num]
6007	IAFTU ID=[num] Config Location=[num]
6008	IAFTU Serial = [str]
6009	Partition #[num] MD5 Hash = [str]
6010	Incrementing Value Memory Test = PASSED
6011	Walking Ones Memory Test = PASSED
6012	Walking Zero's Memory Test = PASSED
6013	Inverse Address Memory Test = PASSED
6014	Fixed Pattern Memory Test = PASSED
6220	Created #[num] navigation sensor "[str]".
6221	Opened navigation serial input at port "[str]" with [num] bps baud rate.
6222	Spawn navigation [str] ([num]) task.
6223	Navigation sensor [str] started in [str] task.
6224	Task Name=[str] Stack Size=[num] Priority=[num]



CODE	MESSAGE
6225	Received initial JAVAD GPS time from [str]. [num] wk [num] ([num]) sec
6226	JAVAD reply from [str]: [str]
6227	Opened navigation UDP input at port [str]:[num]
6300	CASS Version = [str]
6301	MDL Mission Name = [str]
6302	MDL Rules Revision = [str]
6303	MDL Stored CRC = [num]
6304	MDL Computed CRC = [num]
6305	MDL CRC Verification = [str]
6306	MDL XML Checksum = [num]
6400	Opened user command serial input at port "[str]" with [num] bps baud rate.
6401	Spawn user command [str] ([num]) task.
6402	Start [str] task.
6403	Task Name=[str] Stack Size=[num] Priority=[num]
6700	Opened telemetry serial output at port "[str]" with [num] bps baud rate.
6701	Spawn telemetry [str] ([num]) task.
6702	Start [str] task.
6703	Task Name=[str] Stack Size=[num] Priority=[num]

Table 43: Initialization Information Report Messages (6000 – 6999)

19.4 RECOVERABLE ERRORS REPORT MESSAGES (7000 – 7999)

CODE	MESSAGE
7000	IAFTU test mode is disabled when attempting to stop resetting the watchdog.
7001	TI ADC 0 (channel=not received): 0=[num] 1=[num] 2=[num] 3=[num] 4=[num] 5=[num] 6=[num] 7=[num] 8=[num] 9=[num] 10=[num] 11=[num] 12=[num] 13=[num] 14=[num] 15=[num]
7002	TI ADC 1 (channel=not received): 0=[num] 1=[num] 2=[num] 3=[num] 4=[num] 5=[num] 6=[num] 7=[num] 8=[num] 9=[num] 10=[num] 11=[num] 12=[num] 13=[num] 14=[num] 15=[num]
7003	System power is not good.



CODE	MESSAGE
7004	Liftoff detection transceiver is not good.
7005	Watchdog circuit is not enabled when it should be.
7006	Watchdog circuit is not disabled when it should be.
7007	[num] multi-bit error(s) detected in ECC memory.
7008	System clock rate is [num], which should be [num] ticks per second.
7009	IAFTU, CASS, and circuit states are not in agreement with each other.
7010	Watchdog transceiver is not enabled when it should be.
7011	Watchdog transceiver is not disabled when it should be.
7012	IAFTU Serial = NO SERIAL
7013	Unknown exception.
7014	Walking Ones Memory Test = NOT TESTED
7015	Walking Zero's Memory Test = NOT TESTED
7016	Inverse Address Memory Test = NOT TESTED
7017	Fixed Pattern Memory Test = NOT TESTED
7018	Memory test result is not available.
7019	MainManagerIf or IfProxy message queue timed out, returned an error, or Transaction ID don't match.
7020	MainManager time out of 10ms time slot.
7021	MainIf::run() has changed to STOP PROCESSING.
7200	Cannot decode body length field ([num], [num], [num]) in rE from [str].
7201	Upcoming [num]-byte message from [str] is longer than expected for [num]-byte JAVAD rE.
7202	Upcoming [num]-byte message from [str] is longer than expected for [num]-byte JAVAD rV.
7203	Upcoming [num]-byte message from [str] will not fit in [num]-byte data buffer.
7204	Data size ([num] bytes) is not valid for the JAVAD message from [str].
7205	Identifier field ([num], [num]) is not recognized in the JAVAD message from [str].
7204	Data size ([num] bytes) is not valid for rE from [str].
7205	Identifier field ([num], [num]) is not valid in rE from [str].
7206	Cannot decode body length field ([num], [num], [num]) in rE from [str].



CODE	MESSAGE
7207	Body length field ([num] bytes) is not valid in rE from [str]; expected [num] bytes.
7208	CRC field is not valid in rE from [str]. (stored=[num], computed=[num])
7209	GPS week field ([num]) is unknown in the rE message from [str].
7210	GPS milliseconds field ([num]) is out of range in rE message from [str]; expected 0 to 604800000.
7211	Data size ([num] bytes) is not valid for rV from [str].
7212	Identifier field ([num], [num]) is not valid in rV from [str].
7213	Cannot decode body length field ([num], [num], [num]) in rV from [str].
7214	Body length field ([num] bytes) is not valid in rV from [str]; expected [num] bytes.
7215	CRC field is not valid in rV from [str]. (stored=[num], computed=[num])
7216	rV JAVAD message is from [str] is discarded because the rE JAVAD message is not received yet.
7217	Sample number field ([num]) in rV does not match to sample number field ([num]) in the last rE from [str].
7218	Fail to adjust GPS time ([num] wk [num] ([num]) sec) with time delta ([num]) from [str].
7219	Data size ([num] bytes) is not valid for RE from [str].
7220	Identifier field ([num], [num]) is not valid in RE from [str].
7221	Cannot decode body length field ([num], [num], [num]) in RE from [str].
7222	Body length field ([num] bytes) is not valid in RE from [str]; expected [num] bytes.
7223	Data size ([num] bytes) is not valid for ER from [str].
7224	Identifier field ([num], [num]) is not valid in ER from [str].
7225	Cannot decode body length field ([num], [num], [num]) in ER from [str].
7226	Body length field ([num] bytes) is not valid in ER from [str]; expected [num] bytes.
7227	JAVAD error from [str]: [str]
7228	Data size ([num] bytes) is not valid for the NovAtel message from [str].
7229	Sync not found in message ([num] bytes) from [str].
7230	Body length field ([num] bytes) is not valid for message data size ([num] bytes) from [str].
7231	CRC field is not valid in the NovAtel message from [str]. (stored=[hex], computed=[hex])
7232	Received unhandled NovAtel msg Id [num] from [str].
7233	Received invalid NovAtel DOP value(s) from [str].



CODE	MESSAGE
7234	Unsupported NovAtelOEM model enum [num] specified for [str].
7250	NavigationManagerIfProxy message queue timed out, returned an error, or Transaction Id didn't match.
7251	Unknown exception.
7300	Invalid CASS state [str] when enabling CASS logic.
7301	Invalid IAFTU state [str] when enabling CASS logic.
7302	IAFTU health is not good ([num]) when enabling CASS logic.
7303	Invalid CASS state [str] when disabling CASS logic.
7304	Invalid IAFTU state [str] when disabling CASS logic.
7400	Upcoming [num]-byte message from [str] is longer than expected for [num]-byte user command.
7401	Data size ([num] bytes) is not valid.
7402	Sync byte ([num]) is not valid in user command message.
7403	Version byte ([num]) is not valid in user command message.
7404	Checksum in the telemetry message is not valid. (stored=[num], computed=[num])
7405	Message type field ([num]) is invalid in user command message.
7406	Processor ID field ([num]) is not valid in user command message.
7407	Body length field ([num]) is not valid in user command message.
7408	Command field ([num]) is not recognized in user command message.
7409	Previous user command ([num]) is skipped and not executed because a newer user command has replaced it.
7410	User command ([num]) is not allowed after liftoff.
7411	Fail to process user command ([num]).
7412	User command ([num]) is not recognized.
7413	Cannot enable termination circuit due to not good IAFTU health status.
7414	Cannot enable termination circuit due to wrong IAFTU state, [str]; expected [str] or [str].
7415	Cannot enable termination circuit due to wrong CASS state, [str]; expected [str].
7416	Cannot enable termination circuit due to wrong CASS arm status, [str]; expected [str].
7417	Cannot enable termination circuit due to wrong CASS destruct status, [str]; expected [str].



CODE	MESSAGE
7418	Cannot enable termination circuit due to not good IAFTU health status.
7419	Cannot enable termination circuit due to wrong IAFTU state, [str]; expected [str] or [str].
7420	Cannot enable termination circuit due to wrong CASS state, [str]; expected [str].
7421	Cannot enable termination circuit due to wrong CASS arm status, [str]; expected [str].
7422	Cannot enable termination circuit due to wrong CASS destruct status, [str]; expected [str].
7423	Cannot enable watchdog circuit due to not good IAFTU health status.
7424	Cannot enable watchdog circuit due to not enabled termination circuit.
7425	Cannot enable watchdog circuit due to wrong IAFTU state, [str]; expected [str].
7426	Cannot enable watchdog circuit due to wrong CASS state, [str]; expected [str].
7427	Cannot enable watchdog circuit due to wrong CASS arm status, [str]; expected [str].
7428	Cannot enable watchdog circuit due to wrong CASS destruct status, [str]; expected [str].
7429	Cannot enable watchdog circuit due to not good IAFTU health status.
7430	Cannot enable watchdog circuit due to not enabled termination circuit.
7431	Cannot enable watchdog circuit due to wrong IAFTU state, [str]; expected [str].
7432	Cannot enable watchdog circuit due to wrong CASS state, [str]; expected [str].
7433	Cannot enable watchdog circuit due to wrong CASS arm status, [str]; expected [str].
7434	Cannot enable watchdog circuit due to wrong CASS destruct status, [str]; expected [str].
7435	Cannot safe IAFTU due to wrong IAFTU state, [str]; expected [str] or [str].
7436	Cannot enable test mode due to wrong IAFTU state, [str]; expected [str].
7437	Cannot stop resetting watchdog due to not enabled watchdog circuit.
7700	Unknown exception.
7701	Array of queue message sizes is not valid.
7702	Array of queue messages is not valid.
7703	Dropped [num] telemetry messages. VxWorks error [num], [str].
7704	Fail to give enqueue semaphore ([num]) in Telemetry Manager. VxWorks error [num], [str].
7705	Fail to take enqueue semaphore ([num]) in Telemetry Manager. VxWorks error [num], [str].
7706	Fail to give print semaphore ([num]) in Telemetry Manager. VxWorks error [num], [str].



CODE	MESSAGE
7707	Fail to take print semaphore ([num]) in Telemetry Manager. VxWorks error [num], [str].
7708	TelemetryManagerIf or IfProxy message queue timed out, returned an error, or Transaction Id didn't match.
7800	Re-synced system time from [num] wk [num] ([num]) sec to [num] wk [num] ([num]) sec.
7801	Fail to take read-and-write time semaphore ([num]) in Time Manager. VxWorks error [num], [str].
7802	TimeManagerProxy or IfProxy message queue timed out, returned an error, or Transaction Id didn't match.
7803	TimeManagerIfProxy semaphore takes an error or timeout.
7804	TimeManagerIfProxy semaphore gives an error or timeout.
7805	Nanosleep time ([num]) is out of the acceptable range of [num] to 1.0.
7940	Fail to send [num] bytes of data to serial output at "[str]."
7960	Fail openInputOutput at [host]:[port]. Already open.
7961	Fail closeInputOutput at [host]:[port]. Already closed.
7962	Fail receiveData UDP socket is not opened at [host]:[port].
7963	receiveData called with an invalid buffer.
7964	Fail receiveData at [host]:[port]. VxWorks error [num], [str].
7965	Fail sendData UDP socket is not opened at [host]:[port].
7966	sendData called with an invalid buffer.
7967	Fail sendData at [host]:[port]. VxWorks error [num], [str].

Table 44: Recoverable Errors Report Messages (7000 – 7999)

19.5 UNRECOVERABLE FATAL REPORT MESSAGES (8000 – 8999)

CODE	MESSAGE
8000	Startup built-in test failed for three immediately consecutive times.
8001	AFSS ID ([num]) is out of range; expected [MIN_IAFTU_ID] to [MAX_IAFTU_ID].
8002	Time must be synced in order to change the IAFTU state from [str] to [str].
8003	CASS must be in the Ready for Rule Processing state in order to change the IAFTU state from [str] to [str].
8004	CASS must be in Rule Processing state in order to change the IAFTU state from [str] to [str].
8005	IAFTU state [str] is invalid when attempting to change the state to [str].



CODE	MESSAGE
8006	IAFTU must be healthy in order to change the IAFTU state from [str] to [str].
8007	IAFTU state must be Standby in order to change IAFTU state from [str] to [str].
8008	CASS must be in Rule Processing state in order to change the IAFTU state from [str] to [str].
8009	CASS must not recommend destruct in order to change the IAFTU state from [str] to [str].
8010	IAFTU must be healthy in order to change the IAFTU state from [str] to [str].
8011	IAFTU state must be Flight Enabled in order to change the IAFTU state from [str] to [str].
8012	CASS must be in Rule Processing state in order to change the IAFTU state from [str] to [str].
8013	CASS must recommend destruct in order to change the IAFTU state from [str] to [str].
8014	IAFTU state must be Standby or Flight Enabled in order to change the IAFTU state from [str] to [str].
8015	Unknown exception.
8016	Built-in test failed for three immediately consecutive times.
8017	Boot information is not available.
8018	Incrementing Value Memory Test = FAILED
8019	Incrementing Value Memory Test = UNKNOWN
8020	Walking Ones Memory Test = FAILED
8021	Walking Ones Memory Test = UNKNOWN
8022	Walking Zero's Memory Test = FAILED
8023	Walking Zero's Memory Test = UNKNOWN
8024	Inverse Address Memory Test = FAILED
8025	Inverse Address Memory Test = UNKNOWN
8026	Fixed Pattern Memory Test = FAILED
8027	Fixed Pattern Memory Test = UNKNOWN
8028	An instance of [str] program has started already.
8029	Unknown exception.
8030	MainManager semaphore give error
8031	MainManager semaphore take error
8032	Incrementing Value Memory Test = NOT TESTED



CODE	MESSAGE
8033	Fail to create queue semaphore in MainManagerIfProxy. VxWorks error [num], [str].
8034	Fail to create queue semaphore in MainIf. VxWorks error [num], [str].
8035	MainManagerIf or IfProxy message queue timed out, returned an error, or Transaction Id didn't match.
8036	MainManagerIf Encounted unhandled function enumeration.
8037	[num] multi-bit error(s) detected in ECC memory.
8100	Configuration location [num] in NAND is out of range; expected between [num] (inclusive) and [num] (exclusive).
8101	Fail to allocate memory for MDL in Configuration.
8102	MDL size ([num] bytes) is out of range; expected between [num] (exclusive) and [num] (exclusive).
8103	Fail to create AFA::MDL_Tree object.
8104	MDL CRC is not valid. (stored=[num], computed=[num])
8105	MDL reader object is not valid.
8106	MDL reader object is not valid.
8120	Fail to create XNandPs object.
8121	Fail to initialize Xilinx NAND input/output. Xilinx error [num].
8122	Fail to allocate memory for page buffer in Xilinx NAND.
8123	Fail to read [num]-byte page from NAND at [num]—Xilinx error [num].
8200	Fail to allocate memory for an array of navigation tasks in Navigation Manager.
8201	Navigation sensor name "[str]" for parameter "[str]" is not valid.
8202	Navigation sensor name "[str]" is defined more than once.
8203	Too many navigation sensor names are defined; maximum [MAX_SENSOR_COUNT].
8204	Too few navigation sensor names are defined; minimum [MIN_SENSOR_COUNT].
8205	Fail to create queue semaphore in NavigationManagerIfProxy. VxWorks error [num], [str].
8206	Fail to give data semaphore ([num]) in NavigationManagerIfProxy. VxWorks error [num], [str].
8207	Fail to take command semaphore ([num]) in NavigationManagerIfProxy. VxWorks error [nm], [str].
8208	NavigationManagerIfProxy applyConfig failed to send Sensor Names over the Queue.



CODE	MESSAGE
8209	NavigationManagerIf or IfProxy message queue timed out, returned an error, or Transaction Id didn't match.
8210	NavigationManagerIf applyConfig msgQReceive() received the wrong function message.
8211	NavigationManagerIf Encounted unhandled function enumeration.
8212	Unknown exception.
8250	Fail to create data semaphore in [str] decoder. VxWorks error [num], [str].
8251	Fail to allocate memory for data buffer in JAVAD Navigation Decoder.
8252	Navigation sensor name "[str]" defined in MDL is not recognized; expected "GPSCrossStrap," "GPSLocal," or "NavINS".
8253	Fail to create SerialInputOutput object.
8254	Serial Input Output object is not valid.
8255	Fail to spawn navigation [str] task. VxWorks error [num], [str].
8256	Unknown exception.
8257	Array of bytes for the data buffer is not valid.
8258	Array of bytes for the data buffer is not valid.
8259	Fail to give data semaphore ([num]) in [str] decoder. VxWorks error [num], [str].
8260	Fail to take read-only data semaphore ([num]) in [str] decoder. VxWorks error [num], [str].
8261	Fail to take read-and-write data semaphore ([num]) in [str] decoder. VxWorks error [num], [str].
8262	Array of bytes for the data buffer is not valid.
8263	Array of bytes for the data buffer is not valid.
8264	Array of bytes for the data buffer is not valid.
8265	Array of bytes for the data buffer is not valid.
8266	Fail to construct NavigationTask, unknown/unsupported sensor type.
8267	Fail to allocate memory for data buffer in NovAtel Navigation Decoder.
8268	Fail to create UdpInputOutput object.
8269	Fail to create NovAtelOEM object.
8270	UDP Input Output object is not valid.



CODE	MESSAGE
8300	CASS object is not null when attempting to create a new CASS object.
8301	Fail to create AFA::Master object.
8302	CASS state "[str]" ([num]) is not valid after performing CASS built-in-test.
8303	SamplePeriod ([num] ([num])) configured in MDL is not supported; expected [num] seconds.
8304	CASS object is not valid.
8305	Fail to get CASS database variable index for variable "[str]."
8306	CASS object is not valid.
8307	CASS value "DestructSignal" ([num] ([num])) is corrupted; expected [num] ([num]).
8308	CASS object is not valid.
8309	CASS object is not valid.
8310	Fail to enable CASS logic; CASS state is [str].
8311	CASS object is not valid.
8312	Fail to disable CASS logic; CASS state is [str].
8313	CASS object is not valid.
8314	CASS object is not valid.
8315	CASS logic state ([num]) is not valid; expected [num] or [num].
8316	CASS object is not valid.
8317	CASS arm state ([num]) is not valid; expected [num], [num], or [num].
8318	CASS object is not valid.
8319	CASS destruct state ([num]) is not valid; expected [num], [num], or [num].
8320	CASS object is not valid.
8321	CASS database variable index for "dstRuleCount" is null.
8322	CASS object is not valid.
8323	CASS database variable index for "DestructSignal" is null.
8324	CASS object is not valid.
8325	CASS database variable index for "isValidNavData" is null.
8326	CASS object is not valid.



CODE	MESSAGE
8327	CASS database variable index for "Latency" is null.
8328	CASS object is not valid.
8329	CASS database variable index for "NoDataTime" is null.
8330	CASS object is not valid.
8331	CASS database variable index for "Perigee" is null.
8332	CASS object is not valid.
8333	CASS database variable index for "TFLO" is null.
8334	CASS object is not valid.
8335	CASS database variable index for "ValidSensorCount" is null.
8336	CASS object is not valid.
8337	CASS database variable index for "haveLiftOff" is null.
8338	CASS object is not valid.
8339	CASS object is not valid.
8340	CASS object is not valid.
8400	Fail to create queue semaphore in User Command. VxWorks error [num], [str].
8401	Fail to allocate memory for data buffer in User Command.
8402	Fail to create SerialInputOutput object.
8403	Serial Input Output object is not valid.
8404	Fail to spawn user command "[str]" task. VxWorks error [num], [str].
8405	Unknown exception.
8406	Array of bytes for the data buffer is not valid.
8407	Array of bytes for the data buffer is not valid.
8408	Array of bytes for the data buffer is not valid.
8409	Fail to give data semaphore ([num]) in User Command. VxWorks error [num], [str].
8410	Fail to take command semaphore ([num]) in User Command. VxWorks error [nm], [str].
8411	Fail to create UdpInputOutput object.
8500	Fail to write pattern [num] (ENABLE_A) to FPGA register at [num]; result pattern is [num].



CODE	MESSAGE
8501	Fail to write pattern [num] (ENABLE_B) to FPGA register at [num]; result pattern is [num].
8502	Fail to write pattern [num] (SAFE_A) to FPGA register at [num]; result pattern is [num].
8503	Fail to write pattern [num] (SAFE_B) to FPGA register at [num]; result pattern is [num].
8504	Fail to write pattern [num] (unlatch ENABLE_A) to FPGA register at [num]; result pattern is [num].
8505	Fail to write pattern [num] (unlatch ENABLE_B) to FPGA register at [num]; result pattern is [num].
8506	Fail to write pattern [num] (unlatch SAFE_A) to FPGA register at [num]; result pattern is [num].
8507	Fail to write pattern [num] (unlatch SAFE_B) to FPGA register at [num]; result pattern is [num].
8508	Fail to write pattern [num] (WD_ENABLE_A) to FPGA register at [num]; result pattern is [num].
8509	Fail to write pattern [num] (WD_ENABLE_B) to FPGA register at [num]; result pattern is [num].
8510	Fail to write pattern [num] (TERM1_HI on) to FPGA register at [num]; result pattern is [num].
8511	Fail to write pattern [num] (TERM1_LO on) to FPGA register at [num]; result pattern is [num].
8512	Fail to write pattern [num] (TERM2_HI on) to FPGA register at [num]; result pattern is [num].
8513	Fail to write pattern [num] (TERM2_LO on) to FPGA register at [num]; result pattern is [num].
8514	Fail to write pattern [num] (NTERM1_HI off) to FPGA register at [num]; result pattern is [num].
8515	Fail to write pattern [num] (NTERM1_LO off) to FPGA register at [num]; result pattern is [num].
8516	Fail to write pattern [num] (NTERM2_HI off) to FPGA register at [num]; result pattern is [num].
8517	Fail to write pattern [num] (NTERM2_LO off) to FPGA register at [num]; result pattern is [num].
8518	Too many consecutive indeterminate states ([num]) when processing CASS recommendations.
8519	CASS destruct state ([str], [num]) is not consistent; expected [str], [num].
8520	CASS destruct state ([str], [num]) is not consistent; expected [str], [num].
8640	Fail to initialize Xilinx SPI. Xilinx error [num].
8641	Fail to set options for Xilinx SPI. Xilinx error [num].
8642	Fail to set clock prescaler for Xilinx SPI. Xilinx error [num].
8643	Fail to set selection to ADC 0 for Xilinx SPI. Xilinx error [num].
8644	Fail to apply initial Auto-2 mode register settings for ADC 0—Xilinx error [num].
8645	Fail to set selection to ADC 1 for Xilinx SPI. Xilinx error [num].
8646	Fail to apply initial Auto-2 mode register settings for ADC 1—Xilinx error [num].



CODE	MESSAGE
8647	Fail to set selection to ADC 0 for Xilinx SPI. Xilinx error [num].
8648	Fail to apply Auto-2 mode register settings for ADC 0—Xilinx error [num].
8649	Fail to read frame from ADC 0—Xilinx error [num].
8650	Fail to set selection to ADC 1 for Xilinx SPI. Xilinx error [num].
8651	Fail to apply Auto-2 mode register settings for ADC 1—Xilinx error [num].
8652	Fail to read frame from ADC 1—Xilinx error [num].
8700	Fail to allocate memory for an array of queue message sizes in Telemetry Manager.
8701	Fail to allocate memory for an array of queue messages in Telemetry Manager.
8702	Fail to allocate memory for an array of message bytes in Telemetry Manager.
8703	Fail to create enqueue semaphore in Telemetry Manager. VxWorks error [num], [str].
8704	Fail to create print semaphore in Telemetry Manager. VxWorks error [num], [str].
8705	Fail to create SerialInputOutput object.
8706	Serial Input Output object is not valid.
8707	Fail to spawn telemetry [str] task. VxWorks error [num], [str].
8708	Serial Input Output object is not valid.
8709	Telemetry semaphore give error.
8710	Telemetry semaphore take error
8711	TelemetryManagerIf or IfProxy message queue timed out, returned an error, or Transaction Id didn't match.
8712	Fail to create queue semaphore in TelemetryManagerIfProxy. VxWorks error [num], [str].
8713	TelemetryManagerIf Encounted unhandled function enumeration.
8714	Unknown exception.
8720	Fail to allocate memory for an array of message bytes in Telemetry Message.
8800	Fail to allocate memory for an array of drift cycles in Time Manager.
8801	Fail to create a time semaphore in Time Manager. VxWorks error [num], [str].
8802	Fail to give time semaphore ([num]) in Time Manager. VxWorks error [num], [str].
8803	Fail to take read-only time semaphore ([num]) in Time Manager. VxWorks error [num], [str].



CODE	MESSAGE
8804	Fail to take read-and-write time semaphore ([num]) in Time Manager. VxWorks error [num], [str].
8805	Fail to get the current system clock.
8806	TimeManagerIf or IfProxy message queue timed out, returned an error, or Transaction Id didn't match.
8807	TimeManagerIf Encounted unhandled function enumeration!
8808	Fail to create queue semaphore in TimeManagerIfProxy. VxWorks error [num], [str].
8809	TimeManagerIfProxy semaphore give error or timeout.
8810	TimeManagerIfProxy semaphore take error or timeout.
8850	Fail to allocate memory for an array of CPU idle samples 0 in CPU Stats.
8851	Fail to allocate memory for an array of CPU idle samples 1 in CPU Stats.
8852	Fail to set system auxiliary clock rate ([num]).
8853	Fail to connect to system auxiliary clock.
8940	Operation mode ([num]) is invalid in Serial Input Output.
8941	Fail to allocate memory for data buffer in Serial Input Output.
8942	Fail to open serial port "[str]." VxWorks error [num], [str].
8943	Fail to set serial baud rate "[num]." VxWorks error [num], [str].
8944	Fail to set serial hardware options. VxWorks error [num], [str].
8945	Fail to set serial raw TTY discipline. VxWorks error [num], [str].
8946	Fail to set serial read buffer. VxWorks error [num], [str].
8947	Fail to close serial port "[str]." VxWorks error [num], [str].
8948	Wrong operation mode for serial input at "[str]."
8949	Serial input is not opened at "[str]."
8950	Wrong operation mode for serial output at "[str]."
8951	Serial output is not opened at "[str]."
8960	Fail to construct UdpInputOutput [host]:[port]. VxWorks error [num], [str].
8961	Fail to create UDP socket at [host]:[port]. VxWorks error [num], [str].
8962	Fail to bind UDP socket at [host]:[port]. VxWorks error [num], [str].
8963	Fail openInputOutput at [host]:[port]. VxWorks error [num], [str].



CODE	MESSAGE
8964	Fail send/receive wrong mode. VxWorks error [num], [str].

Table 45: Unrecoverable Fatal Report Messages (8000 – 8999)