University of Washington

HuskySat-2 CDH Interface Control Document

ICD-CDH-001

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Revision History

Revision	Date	Change	Author	Approved By	Notes
1	10/6/2025	Subsystem ICD template	Catherine Collison	Systems Team	
2	7/1/26	CDH ICD created	Lauren Wetzel	Systems Team	
3	8/17/26	CDH Electrical Interfaces	Chase Rushing	Systems Team	
4	8/20/2026	CDH Software Interfaces	Eleanor Marso	Systems Team	

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Acronyms & Symbols List

Acronym	Definition
HSL	Husky Satellite Lab
HS-2	HuskySat-2
CDH	Command and Data Handling
UNP	University Nanosatellite Program
LEO	Low Earth Orbit
LOST	LOST Open-Source Star Tracker
FOUND	Found Open-Source Universal Navigational Determiner
COTS	Commercial Off-The-Shelf
ADCS	Attitude Determination and Control System
CDH	Command and Data Handling System
THR	Thermal control subsystem
STR	Structures subsystem
EPS	Electrical Power Subsystem
BMS	Battery management system
PDS	Power distribution system
COM	Communications Subsystem
PCB	Printed Circuit Board
GPS	Global Positioning System
NDA	Non Disclosure Agreement
BBB	Beaglebone Black

Symbol	Definition
**	Number managed by the team, but unable to be provided due to NDA

Purpose and Scope

This Interface Control Document (ICD) defines the **electrical**, **mechanical**, **thermal**, and **data** interfaces required for the **Command and Data Handling (CDH)** subsystem to be successfully integrated into HuskySat-2. The CDH subsystem includes all hardware and software to support the scientific customer of HuskySat-2. Husky Sat-2 (HS-2) is a 3U CubeSat developed by the Husky Satellite Lab (HSL) at the University of Washington in Seattle. Designed to operate in Low Earth Orbit, HS-2 aims to demonstrate the capabilities of its novel navigation technology: LOST (Lost Open-Source Star Tracker) and FOUND (FOUND Open-Source Universal Navigational Determiner). LOST and FOUND enable GPS-independent navigation for small satellites using a unique star tracker and horizon tracker package developed here at HSL. The CDH subsystem includes all hardware and software to support the operation of LOST and FOUND.

CDH

The CDH subsystem has the following hardware components:

Table 1. CDH Hardware

Hardware	Description	Datasheet (Public)
Beaglebone Black (BBB)	Flight computer of HS-2.	https://cdn-shop.adafruit.com/product-files/1996/BBB_SRM.pdf
CDH PCB	PCB that contains the cape for the BBB, MMC Data Storage, eFuses, Thermal and Sun Sensor ADCs, RS-485 Transceivers	[TBR]
CDH USB Cape	PCB that converts BBB USB Pin to Flat Flex Cable	[TBR]

Interface Identification and Definitions

1. Interface Overview

Electrical Interfaces: Defines the power distribution structure, including the 3.3V, 5V, and 12V voltage rails allocated by the power budget. Establishes the physical connectors, pinouts, and signal characteristics managing power and data delivery to the subsystem

Mechanical Interfaces: Captures physical dimensions, mass properties, and mounting requirements of subsystem components, as well as how they interface with each other and the spacecraft structure.

Thermal Interfaces: Specifies the heat generated by each component, establishes operational and survival temperature boundaries, and details the physical conduction paths mounting interfaces that connect the components to the structure.

Software Interfaces: Any exchange of information to, from, or inside the subsystem. Describes the data, data type, connections, and protocols.

1.0 Electrical Interfaces

1.1 - Power

Table 2: CDH Power Interfaces

Section	*Input Voltage (V)*	*Meets Input Voltage Req.*	*TYP Power Draw (W)*	*Power Draw Max (W)*	*TYP Current Draw (A)*
EPS PCB to BBB	5	☑	1.5	2.3	0.300
EPS PCB to CDH PCB (5V rail)	5	☑	0.011	0.0113	2.26e-3
EPS PCB to CDH PCB (3.3V rail)	3.3	☑	0.504	0.753	0.132

1.1.1 EPS PDS to CDH PCB

The CDH nominally receives 2.4 W of power at 5V from the PDS PCB. The peak power draw of the CDH is 2.5 W. The safe mode power draw of the CDH is 2.0 W. In addition to this, the CDH nominally receives 0.55 W of power at 3.3V from the PDS PCB. The peak power draw of the CDH is 0.8 W.

1.1.2 EPS PDS to BBB

The BBB nominally receives 1.5 W of power at 5V from the PDS PCB. The peak power draw of the CDH is 1.518W. The safe mode power draw of the CDH is 0.759 W.

1.2 - Data

Note: The direction is from the reference point of the flight computer.

Section	Signal	Direction	Protocol	Description
LOST Camera	USB	Bidirectional	USB 2.0	USB Camera to USB Hub to BBB

FOUND Camera	USB	Bidirectional	USB 2.0	USB Camera to USB Hub to BBB
eUSB Flash	USB	Bidirectional	USB 2.0	USB Flash Memory to USB Hub to BBB
S-Band Transceiver	RS-485 (Half Duplex)	Bidirectional	UART	TX/RX Signal from Endurosat S-Band Transceiver, half-duplex RS-485 transceived to UART
Sagitta Star Tracker	RS-485 (Full Duplex)	Bidirectional	UART	TX/RX signals from Sagitta Star Tracker, full-duplex RS-485 transceived to UART
GNSS Receiver	LVTTL	RX	UART	TX signals from GNSS Receiver
IMMU	LVTTL	Bidirectional	UART	TX/RX signals from inertial measurement and magnetometer unit
SSD	LVTTL	Bidirectional	eMMC	32GB solid state drive data lines
PDS Current Measurement	LVTTL	Bidirectional	I2C	I2C Signals from INA3221 current measurement device on PDS
BMS Battery Status	LVTTL	Bidirectional	I2C	I2C Signals from battery manager BQ25756E
Sun Sensor ADC	LVTTL	Bidirectional	SPI	SPI Data output and multiplexing of Sun Sensors
Thermocouple Amplifier ADC	LVTTL	Bidirectional	SPI	SPI Data output of Thermocouple Amplifiers
Kapton Heaters	LVTTL	Output	PWM	PWM output for Kapton Heaters
ADCS H-Bridge	LVTTL	Output	PWM	PWM output used in controlling H-bridge for Magnetorquers
Sun Sensor ADC CS	LVTTL	Output	GPIO	SPI chip-select pin for sun sensor analog-to-digital converter
Thermocouple Amplifier ADC CS	LVTTL	Output	GPIO	SPI chip-select pin for thermocouple amplifier analog-to-digital converter
SSD Reset	LVTTL	Output	GPIO	Active-Low reset Signal for solid state drive
PDS PG	LVTTL	Input	GPIO	Active-Low power-good indicator from PDS current manager

USB Hub High Speed Indicator	LVTTL	Input	GPIO	Active-Low indicator of USB2.0 high speed data transfer from USB2514 USB Hub
USB Suspend State Indicator	LVTTL	Input	GPIO	Active-High indicator of downstream USB ports being suspended from USB2514 USB Hub
USB Hub Reset	LVTTL	Output	GPIO	Active-Low reset signal for USB2514 USB Hub
GNSS Receiver Reset	LVTTL	Output	GPIO	Active-Low reset signal for GNSS Receiver
IMMU Restore	LVTTL	Output	GPIO	Active-High restore Signal for Inertial Measurement and Magnetometer Unit
PDS Heartbeat Signal	LVTTL	Output	GPIO	Active-High heartbeat signal for PDS watchdog timer
PDS Watchdog System Reset	LVTTL	Input	GPIO	Active-Low flight computer reset signal received from PDS watchdog timer.
Thermocouple Amplifier ADC Multiplexer	LVTTL	Output	GPIO	3 Active-High pins acting as binary controls for 8 pin multiplexers that control thermocouple amplifier analog-to-digital converter input
Thermocouple Amplifier ADC Data Ready	LVTTL	Input	GPIO	Active-Low interrupt pin from thermocouple amplifier analog-to-digital converter that indicates data is fully read
BMS Status	LVTTL	Input	GPIO	Active-low binary status pins of the battery manager BQ25756E
BMS Interrupt	LVTTL	Input	GPIO	Active-Low interrupt pin of BQ25756E battery controller BQ25756E
BMS Power Good	LVTTL	Input	GPIO	Active-Low indicator pin indicating power-good status of BQ25756E battery manager
FOUND Trigger IN	LVTTL	Output	GPIO	Active-High camera trigger input signal for FOUND camera
FOUND Trigger Out	LVTTL	Input	GPIO	Active-low camera trigger output signal for FOUND camera

LOST Trigger IN	LVTTL	Output	GPIO	Active-High camera trigger input signal for LOST camera
LOST Trigger Out	LVTTL	Input	GPIO	Active-low camera trigger output signal for LOST camera

1.3 Pinouts

1.3.1 BBB Pinout Diagram

Pinout Diagram as of 9-1-2026.

Assignment	Pin	P8	P8	Pin	Assignment
	DGND	1	2	DGND	
SSD	MCC1_DAT6	3	4	MMC1_DAT7	SSD
SSD	MCC1_DAT2	5	6	MMC1_DAT3	SSD
IMMU_SYNC_IN	GPIO_66	7	8	GPIO_67	
IMMU_SYNC_OUT	GPIO_69	9	10	GPIO_68	
ADCS H-Bridge GPIO_3	GPIO_45	11	12	GPIO_44	
ADCS H-Bridge PWM_3	PWM2B	13	14	GPIO_26	
ADCS H-Bridge GPIO_2	GPIO_47	15	16	GPIO_46	
ADCS H-Bridge GPIO_1	GPIO_27	17	18	GPIO_65	
SSD_RESETn	GPIO_22	19	20	MMC1_CMD	SSD
SSD	MMC1_CLK	21	22	MMC1_DAT5	SSD
SSD	MMC1_DAT4	23	24	MMC1_DAT1	SSD
SSD	MMC1_DAT0	25	26	GPIO_66	Found Trigger OUT
TC MUX_1	GPIO_86	27	28	GPIO_88	Found Trigger IN
TC MUX_2	GPIO_87	29	30	GPIO_89	LOST Trigger OUT
TC MUX_3	GPIO_10	31	32	GPIO_11	LOST Trigger IN
TC DRDYn	GPIO_9	33	34	PWM1B	BMS_HEATER_PWM

TC SPI1_CS1	GPIO_8	35	36	GPIO_80	PDS_HB
S-Band Transceiver RX	UART5_TX	37	38	UART5_RX	S-Band Transceiver TX
BMS STAT_1n	GPIO_76	39	40	GPIO_77	RS485_Trans_en
BMS STAT_2n	GPIO_74	41	42	GPIO_75	PDS_PVn
BMS PGn	GPIO_72	43	44	GPIO_73	PDS_Warningn
	GPIO_70	45	46	GPIO_71	PDS_Criticaln

Assignment	Pin	P9	P9	Pin	Assignment
	DGND	1	2	DGND	
	3.3V	3	4	3.3V	
	5V (VDD)	5	6	5V (VDD)	
	5V (SYS)	7	8	5V(SYS)	
	PWR_BUT	9	10	SYS_RESETn	PDS Watchdog Timer Reset
GNSS Receiver RX	UART_4_RX	11	12	GPIO_60	FLASH_SPI1_CS4
GNSS Recevier TX	UART_4_TX	13	14	PWM1A	ADCS H-Bridge PWM_1
GNSS RESETn	GPIO_48	15	16	PWM1B	ADCS H-Bridge PWM_2
FLASH_SPI1_CS3	GPIO_4	17	18	GPIO_5	GNSS PF
PDS/BMS	I2C2_SCL	19	20	I2C2_SDA	PDS/BMS
IMMU TX	UART2_TX	21	22	UART2_RX	IMMU RX
USB2514 SUSP_IND	GPIO_49	23	24	UART1_TX	Sagitta RX
USB2514 HS_INDn	GPIO_117	25	26	UART1_RX	Sagitta TX
USB2514 RESETn	GPIO_125	27	28	SPI1_CS0	Sun ADC SPI1_CS0
Sun sensor ADC + TC Amp	SPI1_D0	29	30	SPI1_D1	Sun sensor ADC + TC Amp
Sun sensor ADC + TC Amp	SPI1_SCLK	31	32	VDD_ADC	
	AIN4	33	34	GND_ADC	
	AIN6	35	36	AIN5	
	AIN2	37	38	AIN3	
	AIN0	39	40	AIN1	
GNSS VPP	GPIO_20	41	42	GPIO_7	FLASH_SPI1_CS2
	DGND	43	44	DGND	

	DGND	45	46	DGND	

1.3.2 PC-104 Pinout Diagram

Assignment	Pin	J1	J1	Pin	Assignment
Reserved by Endurosat S-Band	NC	a1	b1	GND	
Reserved by Endurosat S-Band	NC	a2	b2	SIGNAL	PDS_Criticaln
	NC	a3	b3	SIGNAL	PDS_Warningn
BMS Heater PWM	PWM	a4	b4	SIGNAL	PDS_PVn
BMS_STAT_1	SIGNAL	a5	b5	NC	
BMS_STAT_2	SIGNAL	a6	b6	SIGNAL	BMS_PGn
PDS_HB	SIGNAL	a7	b7	SIGNAL	PDS_WD_RESETn
	NC	a8	b8	SIGNAL	UART0_TX
ADCS_PWM_1	PWM	a9	b9	SIGNAL	UART0_RX
ADCS_GPIO_1	SIGNAL	a10	b10	GND	
ADCS_PWM_2	PWM	a11	b11	SIGNAL	COMM_RS_485_SYS1 B
ACS_GPIO_2	SIGNAL	a12	b12	SIGNAL	COMM_RS_485_SYS1 A
3.3V	POWER	a13	b13	POWER	3.3V
Reserved by Endurosat S-Band	NC	a14	b14	SIGNAL	I2C2_SCL
ADCS_PWM_3	PWM	a15	b15	SIGNAL	I2C2_SDA
ADCS_GPIO_3	SIGNAL	a16	b16	NC	Reserved by Endurosat S-Band
Reserved by Endurosat S-Band	NC	a17	b17	GND	GND Required by Endurosat
Reserved by Endurosat S-Band	NC	a18	b18	NC	

Reserved by Endurosat S-Band	NC	a19	b19	NC	Reserved by Endurosat S-Band
Reserved by Endurosat S-Band	NC	a20	b20	NC	Reserved by Endurosat S-Band
Reserved by Endurosat S-Band	NC	a21	b21	NC	
Reserved by Endurosat S-Band	NC	a22	b22	NC	
	GND	a23	b23	GND	
12V	POWER	a24	b24	POWER	12V
	GND	a25	b25	GND	
5V	POWER	a26	b26	POWER	5V

Assignment	Pin	J2	J2	Pin	Assignment
THR_TC4_T-	SIGNAL	a1	b1	SIGNAL	THR_TC4_T+
THR_TC5_T-	SIGNAL	a2	b2	SIGNAL	THR_TC5_T+
THR_TC6_T-	SIGNAL	a3	b3	SIGNAL	THR_TC6_T+
THR_TC7_T-	SIGNAL	a4	b4	SIGNAL	THR_TC7_T+
THR_TC8_T-	SIGNAL	a5	b5	SIGNAL	THR_TC8_T+
	GND	a6	b6	GND	
	NC	a7	b7	NC	
SUN_SENS5_CH	SIGNAL	a8	b8	SIGNAL	SUN_SENS6_CH
SUN_SENS3_CH	SIGNAL	a9	b9	SIGNAL	SUN_SENS4_CH
SUN_SENS1_CH	SIGNAL	a10	b10	SIGNAL	SUN_SENS2_CH
	GND	a11	b11	GND	
12V	POWER	a12	b12	POWER	12V
3.3V	POWER	a13	b13	POWER	3.3V
	GND	a14	b14	GND	
	GND	a15	b15	GND	
	GND	a16	b16	GND	
5V_PERM	POWER	a17	b17	POWER	5V_PERM

Assignment	Pin	J2	J2	Pin	Assignment
THR_TC4_T-	SIGNAL	a1	b1	SIGNAL	THR_TC4_T+
THR_TC5_T-	SIGNAL	a2	b2	SIGNAL	THR_TC5_T+
THR_TC6_T-	SIGNAL	a3	b3	SIGNAL	THR_TC6_T+
	NC	a18	b18	NC	
	NC	a19	b19	NC	
	NC	a20	b20	NC	
	NC	a21	b21	NC	
	GND	a22	b22	GND	
Battery_PWR	POWER	a23	b23	POWER	Battery_PWR
Battery_PWR	POWER	a24	b24	POWER	Battery_PWR
	GND	a25	b25	GND	
5V	POWER	a26	b26	POWER	5V

2.0 Mechanical Interfaces

2.1 Interface Overview

CDH's mechanical interface to the Structures (STR) subsystem covers its position within the PCB stack, all compressed along the four M3x0.50 structural rods (Grainger 25DM52). Mounting order is shown in the stack diagram (Figure 1); this section lists fastener specs, torque, and mounting facts only. STR is the authoritative source for fastener sizing, torque, and back-out method; see the Structures ICD (ICD-STR-1) Section 2.6.

2.2 Fasteners and Mounting Facts

- CDH carries no dedicated retention nut; it is compressed along with the rest of the Transceiver-Splitter-CDH-Payload PCB zone by the rod preload spanning Tie 2's top-face nut to Tie 1's bottom-face nut.
- Splitter-to-CDH standoff: McMaster 95947A512, M3x0.5 hex standoff, 7.99mm. Structures ICD Index, Table 2.6-2, Fastener ID F-10.
- CDH-to-Tie 1 standoff: same part, 13.73mm, sets the spacing up to Tie 1's bottom-face nut. Table 2.6-2, Fastener ID F-10.
- Tie 1 bottom-face nut: McMaster 93625A100, M3x0.5 nylon-insert locknut, ~0.96 N-m, sits directly above the standoff and directly below Payload PCB -- closes out this zone. Table 2.6-2, Fastener ID F-14.
- CDH is the last board before Payload PCB, which is the top of the rod-compressed portion of the stack (see the Payload PCB and GNSS Receiver mechanical interfaces section).

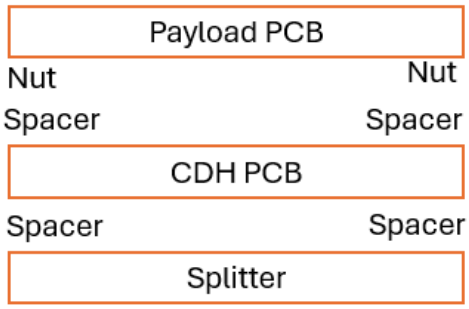


Figure 1: PCB Stack

3.0 Thermal Interfaces

Table 3: Thermal Interfaces

Component	Heat Generation (W)	Min Operating Temperature	Max Operating Temperature	Connections
CDH PCB and support electronics	TBD (board self-dissipation)	-40	85	CDH PCB, standoffs/rails, and secondary structure
USB ports and harness interface	TBD	-40	90	CDH PCB, standoffs/rails, and external harness interface

The Command & Data Handling (CDH) subsystem, centered on a BeagleBone Black processor, is budgeted for an operating temperature range of −40 to +85 °C, with USB-port hardware rated to −90 °C. The BeagleBone is expected to dissipate approximately 1.5 W during sustained processing operations. CDH has no dedicated heater allocation; instead, thermal control relies on passive conduction and potential active monitoring via type K thermocouple under the Thermal subsystem's oversight. To manage the BeagleBone's 1.5 W heat load, heat pipes are under consideration to conduct thermal energy from the processor toward secondary structure elements (PCB, standoffs, and M3 rods, ref. ICD-STR-1 §2.6) and ultimately to the external primary structure.

4.0 - Software Interfaces

4.1 - CDH Software

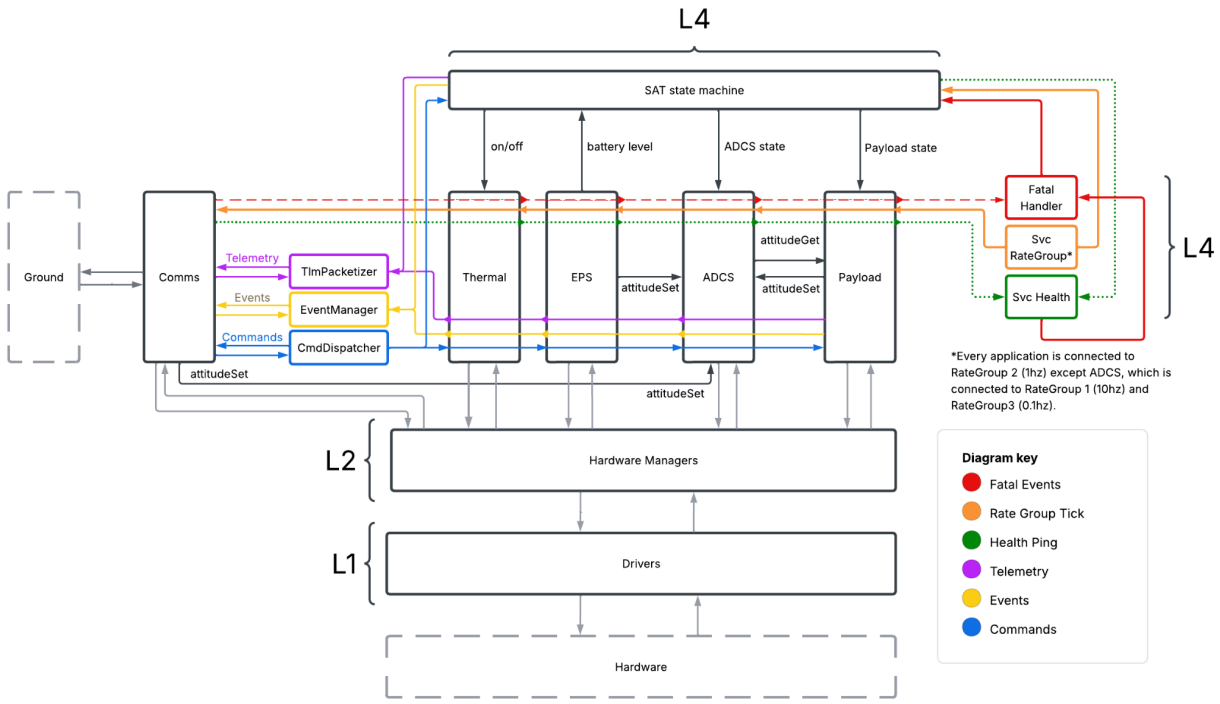


Figure 1

Figure 1 (above) showcases the top-level topology of the software system on the satellite, mainly showcasing how the top-level state machine interacts with each subsystem (application layer) software, and how faults are handled through the provided FatalHandler component.

4.1.1 - Communication Protocol

For HS-2, the communications protocol used for downlinked packets is the CCSDS TM Space Data Link Protocol (based on the CCSDS TM specification (CCSDS 132.0-B-3)). For uplinked packets, the communication protocol to be used is the CCSDS TC Space Data Link Protocol (based on the CCSDS TC specification (CCSDS 232.0-B-4)). F' provides framing capabilities for downlinking telemetry and deframing capabilities for uplinked packets.

4.1.2 - SatStateMachine F’ Component

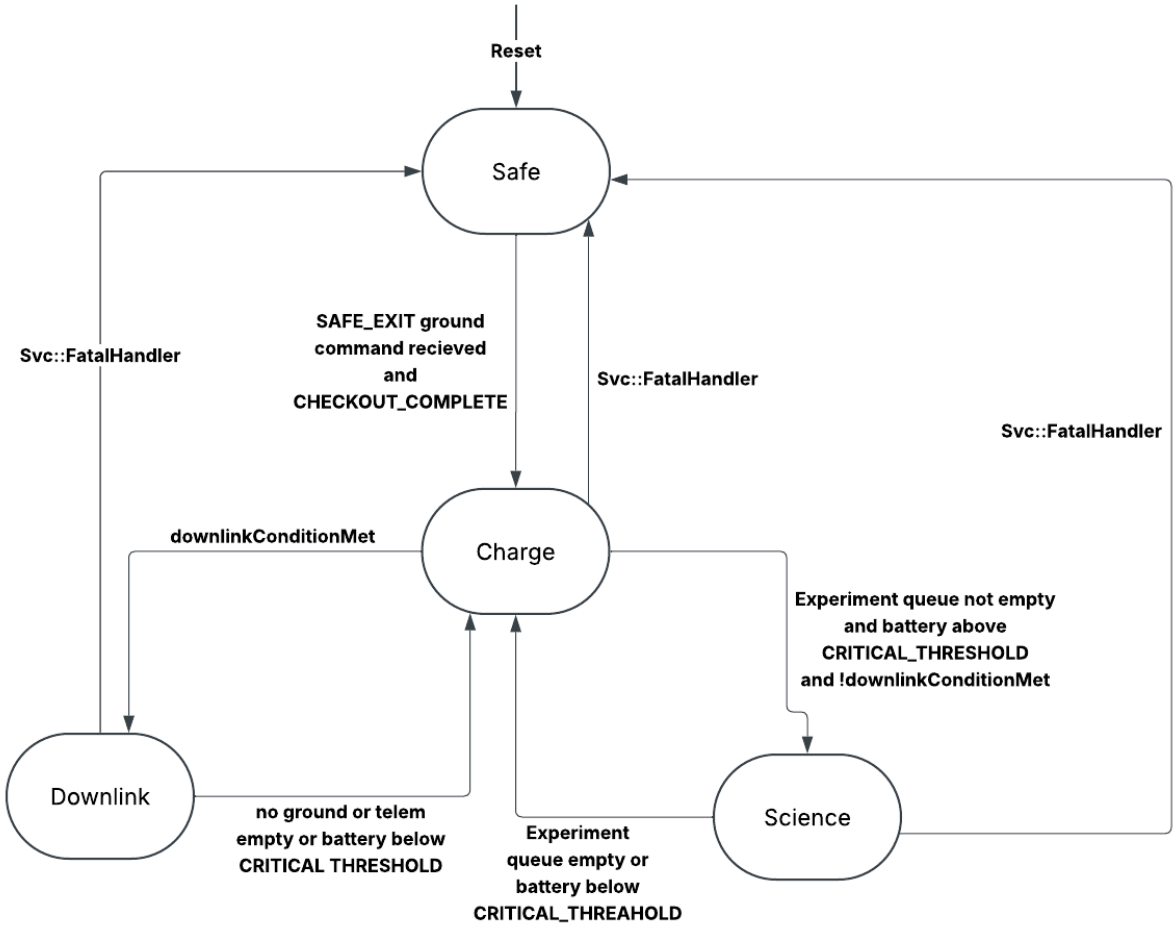


Figure 2

Figure 2 is the state diagram for the top-level state machine of the satellite, showcasing the transitions between each state and the criteria for moving between states. More information about each state can be found in the Mission Design Document and Software Design Document.

Table 4: CDH’ port table:

Name:	I/O:	Type:	Description:
schedIn	input	Svc.sched	Drives submodes and resends mode commands if anything changed at all, RateGroup2 (1 HZ)
adcsModeOut	output	Sat.AdcsMode Port	Delivers the ADCS mode to AdcsApplication

dataColModeOut	output	Sat.DataColModePort	Tells DataCollectionApplication it's mode
scienceInferenceModeOut	output	Sat.ScienceInferenceModePort	Tells ScienceInferenceApplication its mode
commsModeOut	output	Sat.CommsModePort	Tells CommsApplication its mode
orbitStateIn	input	Sat.OrbitStateInPort	Reports whether there is a ground station in view of the satellite
downlinkQueueDepthIn	input	Sat.DownlinkQueueDepthIn	Reports how much data is in the backlog waiting to downlink in bytes
commsReadyIn	input	Sat.CommsReadyInPort	Downlink readiness flag from Comapplication
powerStateGet	output	Sat.PowerStateGetPort	Pulls latest state of charge from EPSApplication
thermalModeOut	output	Sat.ThermalModePort	Tells ThermalApplication its mode
prmGet			

Table 5: CDH F' command table:

Command Name	Opcode [TBRs]	Description	Parameters	Response
SAFE_MODE	0	Forces transition to safe	N/A	Fw.CmdResponse
SAFE_EXIT	1	Requests transition to charge, denied unless CHECKOUT_COMPLETE has been received	N/A	Fw.CmdResponse
CHECKOUT_COMPLETE	2	Ground commands subsystem verification to ok the SAFE_EXIT	N/A	Fw.CmdResponse

		transition		
RESET	3	Forces reentry to SAFE	N/A	Fw.CmdResponse

4.1.4 - CmdDispatcher Component

CmdDispatcher is an F′-provided component that decodes incoming command buffers and dispatches registered commands to the components that implement them. F′ provides the software design document here.

4.1.5 - EventManager Component

EventManager is an F′-provided component that collects component events, applies event filters, and packages events for downlink. F′ provides the software design document here.

4.1.6 - TlmChan Component

TlmChan is an F′-provided component that stores the most recent telemetry-channel values and periodically sends changed channels for downlink. F′ provides the software design document here.

4.1.7 - Health Component

Health is an F′-provided component that pings active components, detects missed responses, and provides the CDH software health-monitoring path. F′ provides the software design document here.

4.1.8 - RateGroupDriver Component

RateGroupDriver is an F′-provided component that divides the primary system tick into scheduled rate groups for CDH collection and control activities. F′ provides the software design document here.

4.1.9 - Version Component

Version is an F′-provided component that reports the flight-software version and build information through the CDH telemetry path. F′ provides the software design document here.

4.1.10 - AssertFatalAdapter Component

AssertFatalAdapter is an F′-provided component that converts framework assertions into FATAL events for the CDH fault-handling path. F′ provides the software design document here.

4.2 CDH Data Interface Details

4.2.1 ADCS Motor Control (CDH to ADCS H-Bridge)

Field	Content
Description	PWM signals to drive H-Bridge motor drivers.
Wired/Wireless	Wired
Communications Protocol	PWM
Signal Type	Digital
Data Format	Pulse-width modulated square wave
Protocol	PWM
Type of Data	Motor drive duty cycle commands
Software	CDH PWM Driver / ADCS Manager
Commands/Inputs	Set PWM frequency and duty cycle
Data rate	1 kHz – 50 kHz PWM frequency

4.2.2 IMMU Data Interface (CDH to IMMU)

Field	Content
Description	UART communication for reading inertial/magnetometer data.
Wired/Wireless	Wired
Communications Protocol	UART
Signal Type	Digital (LVTTL)
Data Format	Serial asynchronous frames
Protocol	UART (Asynchronous)
Type of Data	IMU/Magnetometer readings, Status flags
Software	CDH UART Driver / IMMU Manager
Commands/Inputs	Initialize UART, Read telemetry packets
Data rate	115200 baud (nominal)

4.2.3 GNSS Data Interface (CDH to PAY GNSS)

Field	Content
Description	UART readout of GNSS positional data from Payload.
Wired/Wireless	Wired
Communications Protocol	UART
Signal Type	Digital (LVTTL)
Data Format	NMEA/Binary frames
Protocol	UART
Type of Data	GNSS position, time, velocity
Software	CDH UART Driver / GNSS Manager
Commands/Inputs	Read UART stream
Data rate	9600 - 115200 baud

4.2.4 Payload Imaging (CDH to PAY USB)

Field	Content
Description	USB interface for image data and camera commands.
Wired/Wireless	Wired
Communications Protocol	USB 2.0
Signal Type	Differential Pair
Data Format	Bulk transfer packets
Protocol	USB 2.0
Type of Data	Camera commands, Image raw data
Software	CDH USB Driver / CameraApplication
Commands/Inputs	Capture images, Configure camera settings
Data rate	Up to 480 Mbps

4.2.5 PDS Power Management (CDH to PDS)

Field	Content
Description	Current sensor I2C reading, watchdog heartbeat, and reset signals.
Wired/Wireless	Wired
Communications Protocol	I2C / GPIO
Signal Type	Digital
Data Format	I2C frames / Logic levels
Protocol	I2C / GPIO Handshaking
Type of Data	Current sensor measurements, PDS heartbeat, Reset signals
Software	CDH I2C Driver / CDH GPIO Driver / PDS Manager
Commands/Inputs	Read current sensors, Write watchdog heartbeat, Assert reset
Data rate	100/400 kHz (I2C)

4.2.6 S-Band Transceiver (CDH to COM S-Band)

Field	Content
Description	UART (RS485) communication with S-Band transceiver.
Wired/Wireless	Wired
Communications Protocol	UART (via RS485)
Signal Type	Differential (RS485)
Data Format	Serial frames
Protocol	UART
Type of Data	Uplink/Downlink data packets
Software	CDH UART Driver / CommsManager
Commands/Inputs	Send/Receive packet data
Data rate	9600 - 115200 baud

4.2.7 Sun Sensor Data (CDH to Sun Sensor ADC)

Field	Content
Description	SPI interface to read sun sensor ADC data.
Wired/Wireless	Wired
Communications Protocol	SPI
Signal Type	Digital
Data Format	SPI frames (16-bit)
Protocol	SPI Mode 0
Type of Data	ADC voltage representations for sun sensors
Software	CDH SPI Driver / SunSensorManager
Commands/Inputs	Assert CS, Read ADC registers
Data rate	Up to 5 MHz

4.2.8 Thermal Sensors (CDH to Thermal)

Field	Content
Description	GPIO/SPI interface for thermocouple amplification/ADC.
Wired/Wireless	Wired
Communications Protocol	SPI / GPIO
Signal Type	Digital
Data Format	SPI frames / Binary logic
Protocol	SPI Mode 0 / GPIO
Type of Data	Thermocouple voltage, MUX channel select
Software	CDH SPI Driver / CDH GPIO Driver / ThermocoupleManager
Commands/Inputs	Set MUX address, Read conversion data
Data rate	Up to 5 MHz

4.2.9 Kapton Heater (CDH to Heater)

Field	Content
Description	PWM control signal for Kapton heater regulation.
Wired/Wireless	Wired
Communications Protocol	PWM
Signal Type	Digital
Data Format	PWM square wave
Protocol	PWM
Type of Data	Heater duty cycle commands
Software	CDH PWM Driver / HeaterManager
Commands/Inputs	Set duty cycle
Data rate	1 kHz – 10 kHz

4.2.10 Star Tracker (CDH to Arcsec Star Tracker)

Field	Content
Description	UART (RS485) data exchange for attitude determination.
Wired/Wireless	Wired
Communications Protocol	UART (via RS485)
Signal Type	Differential (RS485)
Data Format	Serial frames
Protocol	UART
Type of Data	Attitude quaternions, timing data
Software	CDH UART Driver / StarTrackerManager
Commands/Inputs	Request attitude, Read packet data
Data rate	921600 baud

5.0 References