ISTsat-1

ISTsat-1 Control Protocol

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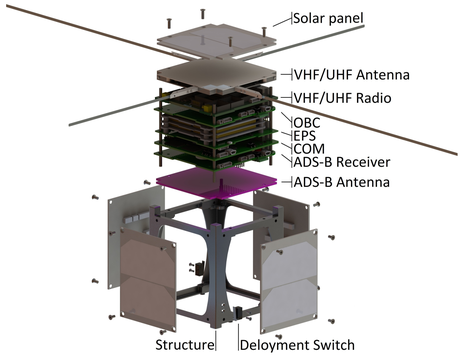
ISTSAT-1 - first nanosatellite project developed by students, professors and radioamateurs at the Instituto Superior Técnico / University of Lisbon in Portugal

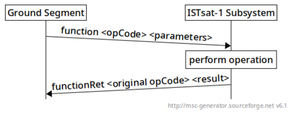
Mission: test compact ADS-B receiver and antenna

INCP: Protocol used for monitorization, control, retrieval of telemetry and experimental results.

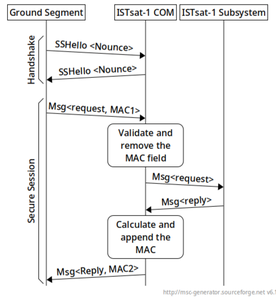


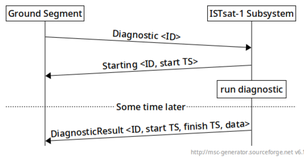
Commands & Diagnostics

- Commands are identified by opcodes.
- *Function* messages trigger commands → results are carried in *functionRet* messages.



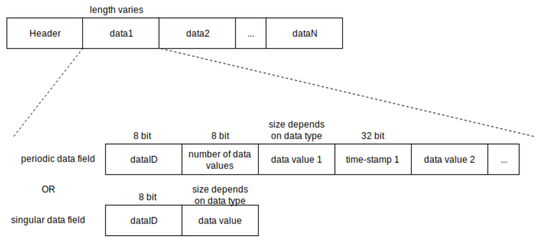
- Commands and diagnostics are protected using Message Authentication Code (MAC).
- MACs are exchanged in the context of a secure session.
- Session are established with the COM subsystem after a handshake phase.





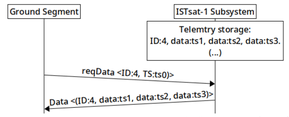
- *Starting* messages indicate the start of a diagnostic.
- Diagnostics may take a while → time related information is important.

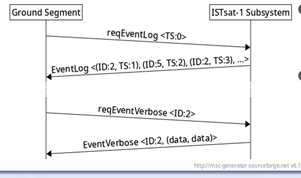
Telemetry retrieval & event reporting



- Singular + Periodic telemetry carried by *Data* messages.
- Periodic data fields → time-series data.
- Singular data fields → instantaneous data.

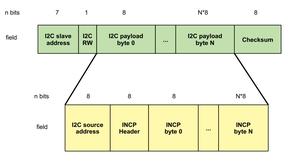
- *reqData* messages convey telemetry.
- Data message ID and timestamp (TS) used as search fields.
- Periodic data older than TS isn't transferred.





- Events are composed by a unique ID and a TS.
- Event specific information is queried using *reqEventVerbose* messages.

Message formats



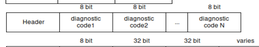
- INCP as the payload of I2C message

header

opcode name

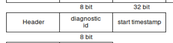
0x01 reqData

0x08 Diagnostic

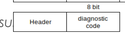


0x0A DiagnosticResult

0x09 DiagnosticStart



0x0B reqDiagnosticResu



opcode name

0x04 reqErrorLog

0x05 ErrorLog

0x02 reqErrorVerbose

0x03 ErrorVerbose

0xXX function

0x0C functionRet

Diagnostic reference

Common

Name	ID	Result
Test I2C bus 0	0xFF	bool: success
Test I2C bus 1	0xFE	bool: success

COM

Name	ID	Result
Loopback-local-CSP	0x00	bool: success
Loopback-local-AX25	0x01	bool: success
Loopback-modem	0x02	bool: success
Loopback-gs	0x03	bool: success
COM-LSw-SRAM current	0x04	uint8: current pair 0; uint8: current pair 1;
COM-LSw-FRAM current	0x05	uint8: current pair 2; uint8: current pair 3; uint8: current pair 4; uint8: current pair 5;

TT&C

Name	ID	Result
Test digital loop	0x08	bool
Test analog loop	0x09	bool
Get TX synth status	0x13	uint8: status
Get RX synth status	0x14	uint8: status

Payload

Name	ID	Result
ADS-B Packet	0x00	bool: success
Filter Response	0x01	bool:success

OBC

Name	ID	Result
Loopback-modem	0x00	bool: success
Loopback-gs	0x01	bool: success
Test-AttitudeAlgorithm	0x02	bool: success
Test-ControlAlgorithm	0x03	bool: success
Test-sensor0	0x04	bool: success
Test-sensor1	0x05	bool: success
Test-sensor2	0x06	bool: success
Test-magnetorquers0	0x07	bool: success
Test-magnetorquers1	0x08	bool: success
Test-magnetorquers2	0x09	bool: success

EPS

Name	ID	Result
Test Converter 1 - 3.3V	0x01	bool: success
Test Converter 2 - 3.3V	0x01	bool: success
Test MPPT X	0x02	bool: success
Test MPPT Y	0x03	bool: success
Test MPPT Z	0x04	bool: success
Test battery	0x05	bool: success
Test battery Charger	0x06	bool: success
Test TT&C	0x07	bool: success
Test OBC	0x08	bool: success
Test COM	0x09	bool: success
Test PL	0x0A	bool: success
Test PV	0x0B	bool: success

Data variables reference

Common

Name	ID	Type	S/P
Time	0xFF	uint32	S
Uptime	0xFE	uint32:	S
Reset Status	0xFD	uint8: 0:on-demand; 1:Watchdog; 2:Power-Up	S
Load-1	0xFC	uint8: 0x00-0%; 0xFF-100%;	S
Load-5	0xFB	uint8	S
Load-15	0xFA	uint8	S
I2C-avg-Tx	0xF9	uint8: bytes/s	S
I2C-avg-Rx	0xF8	uint8: bytes/s	S

COM

Name	ID	Type	S/P
Rx frames	0x00	uint16	S
Tx frames	0x01	uint16	S
Tx bytes	0x02	uint16	S
Tx bytes	0x03	uint16	S
SS-SNRx	0x04	uint16	S
SS-SNTx	0x05	uint16	S
PMA-SNRx	0x06	uint16	S
PMA-SNTx	0x07	uint16	S
COM-I2Cbuf0	0x08	bool	S
COM-I2Cbuf1	0x09	bool	S
COM-RTC	0x0A	bool	S
COM-ExtWD	0x0B	bool	S
COM-CSense1	0x10	uint8	P
COM-CSense2	0x11	uint8	P
COM-LSw0	0x12	bool	P
COM-LSw1	0x13	bool	P
COM-LSw2	0x14	bool	P
COM-LSw3	0x15	bool	P
COM-LSw4	0x16	bool	P
COM-LSw5	0x17	bool	P

EPS

Name	ID	Type	S/P
PV_VoltageX	0x00	int8	P
PV_CurrentX	0x01	int8	P
PV_VoltageY	0x02	int8	P
PV_currentY	0x03	int8	P
PV_VoltageZ	0x04	int8	P
PV_CurrentZ	0x05	int8	P
MPPTX_voltage	0x06	int8	P
MPPTX_current	0x07	int8	P
MPPTY_voltage	0x08	int8	P
MPPTY_current	0x09	int8	P
MPPTZ_voltage	0x0A	int8	P
MPPTZ_current	0x0B	int8	P
Battery_charge	0x0C	int8	P
Charging_status	0x0D	int8	S
Battery_voltage	0x0E	int8	P
Battery_current	0x0F	Int8	P
Battery_temperature	0x10	int8	P
VCC0 _voltage	0x11	int8	P
VCC0 _current	0x12	int8	P
VCC1_voltage	0x13	int8	P
VCC1_current	0x14	int8	P
VCC2_voltage	0x15	int8	P
VCC2_current	0x16	int8	P
VcC3_voltage	0x17	int8	P
VCC3-current	0x18	int8	P
MUX_voltage	0x19	int8	P
MUX_current	0x1A	int8	P
3.3V_voltage	0x1B	int8	P
3.3V_current	0x1C	int8	P

Payload

Name	ID	Type	S/P
# Filters	0x00	uint16	S
Filtering Statistics	0x01	uint32[4]	P
Housekeeping	0x02	int16[2]	P
ADC Sampling Rate	0x03	uint32: Sa/s	S
# Decoded msgs	0x04	uint32	P
# Detected preambles	0x05	uint32	P
Last ADSB msg	0x06	uint8[18]	S

OBC

Name	ID	Type	S/P
OBC-Current	0x00	uint8	P
OBC-Temp	0x01	int8	P
ADCS-Gyro	0x02	3x int16	P
ADCS-Accel	0x03	int16 3x int16	P
ADCS-Mag0	0x04	int16 3x int16	P
ADCS-Mag1	0x05	int16 3x int16	P
ADCS-Euler0	0x06	3x int16	P
ADCS-Euler1	0x07	3x int16	P
ADCS-DC	0x08	3x int16	P
ADCS-Freq	0x09	uint8	P
ADCS-Current0	0x0A	uint8	P
ADCS-Current1	0x0B	uint8	P
ADCS-Current2	0x0C	uint8	P
ADCS-Temp0	0x0D	int8	P
ADCS-Temp1	0x0E	int8	P
ADCS-Temp2	0x0F	int8	P

T&C

Name	ID	Type	S/P
RSSI	0x00	uint8	P
Rx frames	0x01	uint16	S
Tx frames	0x02	uint16	S
Tx bytes	0x03	uint16	S
Tx bytes	0x04	uint16	S
SS-SNRx	0x05	uint16	S
SS-SNTx	0x06	uint16	S
PMA-SNRx	0x07	uint16	S
PMA-SNTx	0x08	uint16	S

Event reference

EPS

Name	ID	Type
Fail-solar-panel rail X	0x00	nil
Fail-solar-panel rail Y	0x01	nil
Fail-solar-panel Z	0x02	nil
Fail MPPT X	0x03	nil
Fail MPPT Y	0x04	nil
Fail MPPT Z	0x05	nil
Fail-buck converter 1, 3.3V	0x06	nil
Fail-buck converter 2, 3.3V	0x07	nil
Fail - MUX	0x08	nil
Fail – Battery Charger	0x09	nil
Fail-Battery	0x0A	nil
BatteryCharge40%	0x0B	nil
BatteryCharge30%	0x0C	nil
BatteryCharge15%	0x0D	nil
Fail-Overload-VCC0	0x0E	nil
Fail-Overload-VCC1	0x0F	nil
Fail-Overload-VCC2	0x10	nil
Fail-Overload-VCC3	0x11	nil
EPS-NormalOp	0x12	nil
EPS-SafeOp	0x13	nil
EPS-LowOp	0x14	nil

Common

Name	ID	Type
I2C0 failed	0xFF	nil
I2C1 failed	0xFE	nil
Invalid INCP msg	0xFD	uint8: opcode; uint8: id
Failure-COM	0xFC	nil
Failure-TT&C	0xFD	nil
Failure-OBC	0xFB	nil
Failure-EPS	0xFA	nil
Failure-Payload	0xF9	nil

OBC

Name	ID	Type
Invalid-MAC	0x00	uint8: opcode; uint8: id
ADCS-determination-failure	0x01	nil
ADCS-control-failure	0x02	nil
ADCS-accelerometer-failure	0x03	nil
ADCS-gyroscope-failure	0x04	nil
ADCS-magnetometer0-failure	0x05	nil
ADCS-magnetometer1-failure	0x06	nil
ADCS-termometer-failure	0x07	nil
ADCS-solar0-failure	0x08	nil
ADCS-solar1-failure	0x09	nil
ADCS-solar2-failure	0x0A	nil
ADCS-solar3-failure	0x0B	nil
ADCS-PWM0-failure	0x0C	nil
ADCS-PWM1-failure	0x0D	nil
ADCS-PWM2-failure	0x0E	nil

COM

Name	ID	Type
Invalid-MAC	0x00	uint8: opcode; uint8: id
COM-CSense-failure	0x01	uint8: id
COM-LSw-failure	0x02	uint8: id
COM-ExtWD-failure	0x03	nil
COM-I2CPw-failure	0x04	uint8: id
COM-RTCPw-failure	0x05	nil

TT&C

Name	ID	Type
TTC failure	0x00	nil

Payload

Name	ID	Type
PL receiver failure	0x00	nil

Command reference

Common

Name	ID	Arguments	Output
WakeUp	0xFF	nil	nil
ResetNormal	0xFE	nil	nil
ResetFull	0xFD	Nil	nil
FirmwareTransfer	0xFC	uint16: block number, uint8: size of block, uint8[]: data	nil
FirmwareCommit	0xFB	uint32: checksum	nil
SetTime	0xFA	uint32: timestamp	nil
GetMemory	0xF9	uint16: start address uint16: length (n)	uint8[]: data uint8: dataSize uint32: checkSum
SetMemory	0xF8	uint8[]: data uint8: dataSize uint32: checkSum	nil

OBC

Name	ID	Arguments	Output
Set-mode	0x00	uint8: mode	nil
Sleep	0x03	uint32: timestamp	nil
I2CSet	0x04	uint8: id; bool: on/off	nil
Set time threshold	0x05	uint32: *timestamp*	nil
Schedule a command	0x06	uint32: *timestamp* incp_command: cmd	<cmd output>
Modem-Reset	0x07	nil	nil
Modem-firmware-transfer	0x08	uint16: block number, uint8: size of block, uint8[]: data	nil
Modem-firmware-commit	0x09	uint32: checksum	nil
RF state	0x0A	bool: on/off	nil
runManeuvering	0x0B	nil	nil
runDesaturation	0x0C	nil	nil
runDetumbling	0x0D	nil	nil
runPointing	0x0E	int16: yaw; int16: pitch; int16:roll;	nil

COM

Name	ID	Arguments	Output
ModemReset	0x00	nil	nil
ModemFirmwareTransfer	0x01	uint16: block number, uint8: size of block, uint8[]: data	nil
ModemFirmwareCommit	0x02	uint32: checksum	nil
COM-I2Cbuf	0x03	uint8: id bool: set	nil
COM-RTC	0x04	bool: set	nil
COM-LSw	0x05	uint8: id bool: set	nil
COM-ExtWD	0x06	nil	nil
COM-CSense	0x07	uint8: id	uint16: data
COM-LSw-Set	0x08	uint8: mask, uint8: value	uint8: value
COM-LSw-Reset	0x09	nil	uint8: value

Beacon

Name	ID	Arguments	Output
SetActive	0x06	bool: active	nil
SetTXPower	0x07	Uint8: percentage 0x00-0%, 0xFF-100%	nil

EPS

Name	ID	Arguments	Output
Set Converter1 3.3V	0x00	bool: on/off	nil
Set Converter2 3.3V	0x01	bool: on/off	nil
Set Battery	0x02	bool: on/off	nil
Set Solar panels	0x03	bool: on/off	nil
Set MPPT X	0x03	bool: on/off	nil
Set MPPT Y	0x04	bool: on/off	nil
Set MPPT Z	0x05	bool: on/off	nil
Set battery threshold	0x06	uint32: value	nil
Set VCC0 power supply	0x07	bool: on/off	nil
Set VCC1 power supply	0x08	bool: on/off	nil
Set VCC2 power supply	0x09	bool: on/off	nil
Set VCC3 power supply	0x0A	bool: on/off	nil
Set VCC0 converter	0x0B	bool: on/off	nil
Set VCC1 converter	0x0C	bool: on/off	nil
Set VCC2 converter	0x0D	bool: on/off	nil
Set VCC3 converter	0x0E	bool: on/off	nil
Set Battery Charger	0x0F	bool: on/off	nil

Payload

Name	ID	Arguments	Output
SetFilterStatus	0x00	uint8: Filter ID, bool: isActive uint8: type	nil
CreateFilterLocation	0x01	uint8: Filter ID, bool: isActive uint32[4]: area bounds	
CreateFilterTime	0x02	uint8: Filter ID, bool: isActive uint32[2]: TS start/stop	
CreateFilterAltitude	0x03	uint8: Filter ID, bool: isActive uint16: altitude, uint8: limit	
CreateFilterVelocity	0x04	uint8: Filter ID, bool: isActive uint16: velocity, uint8: limit	
CreateFilterICAO	0x05	uint8: Filter ID, bool: isActive uint32: ICAO	
CreateFilterTCNumber	0x06	uint8: Filter ID, bool: isActive uint8: TC	
CreateFilterAircraftID	0x07	uint8: Filter ID, bool: isActive uint32[2]: ID	
CreateFilterByField	0x08	uint8: Filter ID, bool: isActive uint8: fieldID, uint8: value uint8: limit	
Get Filters List	0x09	nil	uint8: numFilters uint16[]: filterIDs
Reset Filters	0x0A	nil	nil
Reset Statistics	0x0B	nil	nil
Set Sampling Rate	0x0C	uint32: Sa/s	nil
Reset Sampling Rate	0x0D	nil	nil
TM Housekeeping	0x0E	bool: enable/disable	nil
Science Downlink	0x0F	bool: enable/disable	nil