An Open Source Flight Management System For CubeSats

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sci_Zone

www.sci-zone.com

Overview

- Motivation & Background
- QuickSAT/VMS - key features
- Architecture
- Communications
- Screen Shots
- Road Map

Motivation -
Why a Flight Management System?

- Software is critical to the operation of a satellite
- Most systems are very expensive
- Other solutions are “not ready for prime time”
- Alternatively, “to save money”, the software is written “in house” - which can lead to a range of problems when budgets are constrained.

- ***Goal**: To release an open source based flight management system.*

....enter QuickSAT/VMS

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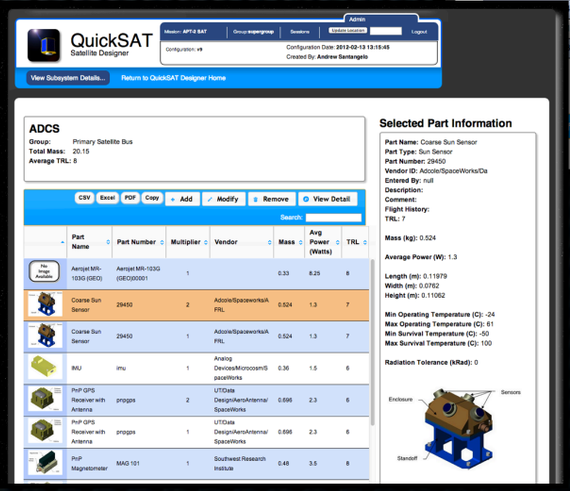
In the beginning... QuickSAT/step_SATdb

- QuickSAT is a web-based Product Lifecycle Management environment for satellite design
- step_SATdb is an open source database
- Multi-platform, uses open source tools
- Modules can be added by the community



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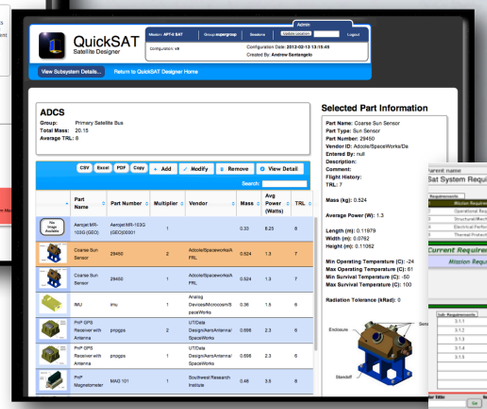
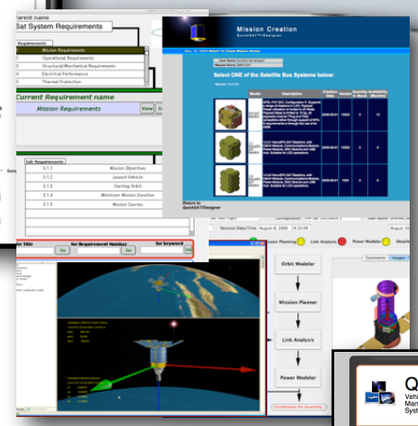
The *step_SATdb* "Cloud"

Customer

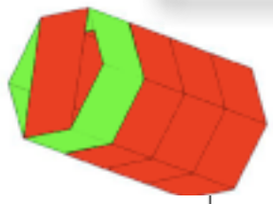
Mission Capture
QuickSAT



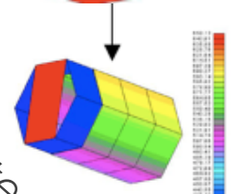


Systems Engineering
QuickSAT

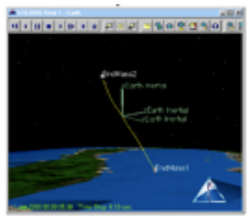
Repository

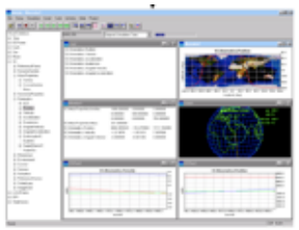


Spacecraft Design
QuickSAT



external tools





Requirements

Systems

Parts/Inventory Control

Design

Test/ Manufacturing

Testing & Verification
QuickSAT

Manufacturing & Assembly
QuickSAT

Supplier

Flight & Ground Control
QuickSAT

Then came...
The world of Aviation!

- sci_Zone commercialized QS code to support the GE Aviation Aircraft Health Management System Project.
- sci_Zone entered into an agreement with GE to use the open source QuickSAT APIs on their “Operational Ground Program” (OGP).
- QuickSAT/Vehicle Management System (VMS) created as an expanded version of the OGP program.

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QuickSAT/VMS

- Broad Use: *Aviation, Satellites, Cars*
- A complete Flight Management System
- Vehicle Health Management & Monitoring
- Vehicle Commanding Services
- Communications services
- Test/Monitoring interface

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QuickSAT/VMS

- Can serve as a stand alone ground station or part of an expanded environment
- Customizable
- Utilizes open source software where possible
- Works on a range of flight hardware
- Web based - PCs, Tablets, etc.
- Certified DO178B for Aviation

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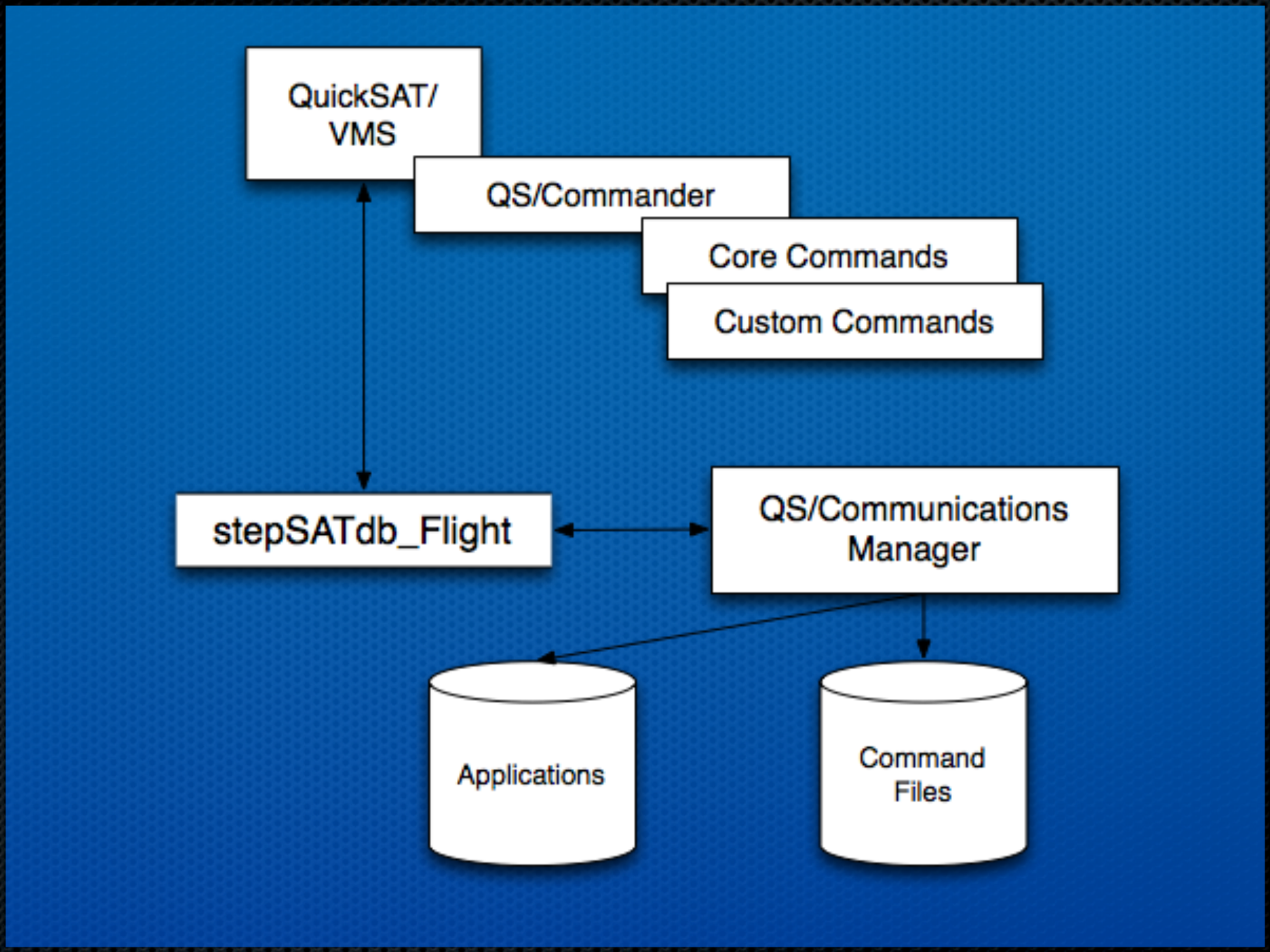
Architecture


QuickSAT/
VMS
QS/Commander
Core Commands
Custom Commands
stepSATdb_Flight
QS/Communications
Manager
Applications
Command
Files

QuickSAT/Designer

- Parts Management
- Parameter Defn
- C&DH
- Mission Flight Plan
- Scheduler
- Xen Tools
- Define Modes
- Mission Conops & Analysis

v6.0

QuickSAT/VMS

- Flight Management
- File Transfer
- Health Monitoring
- Communications
- Configuration Support
- Ground Control

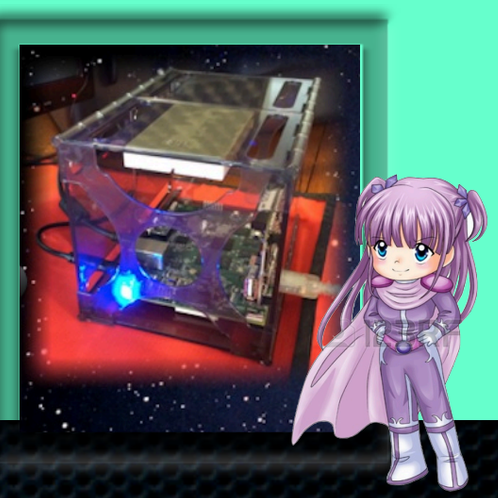
v3.5

Xen

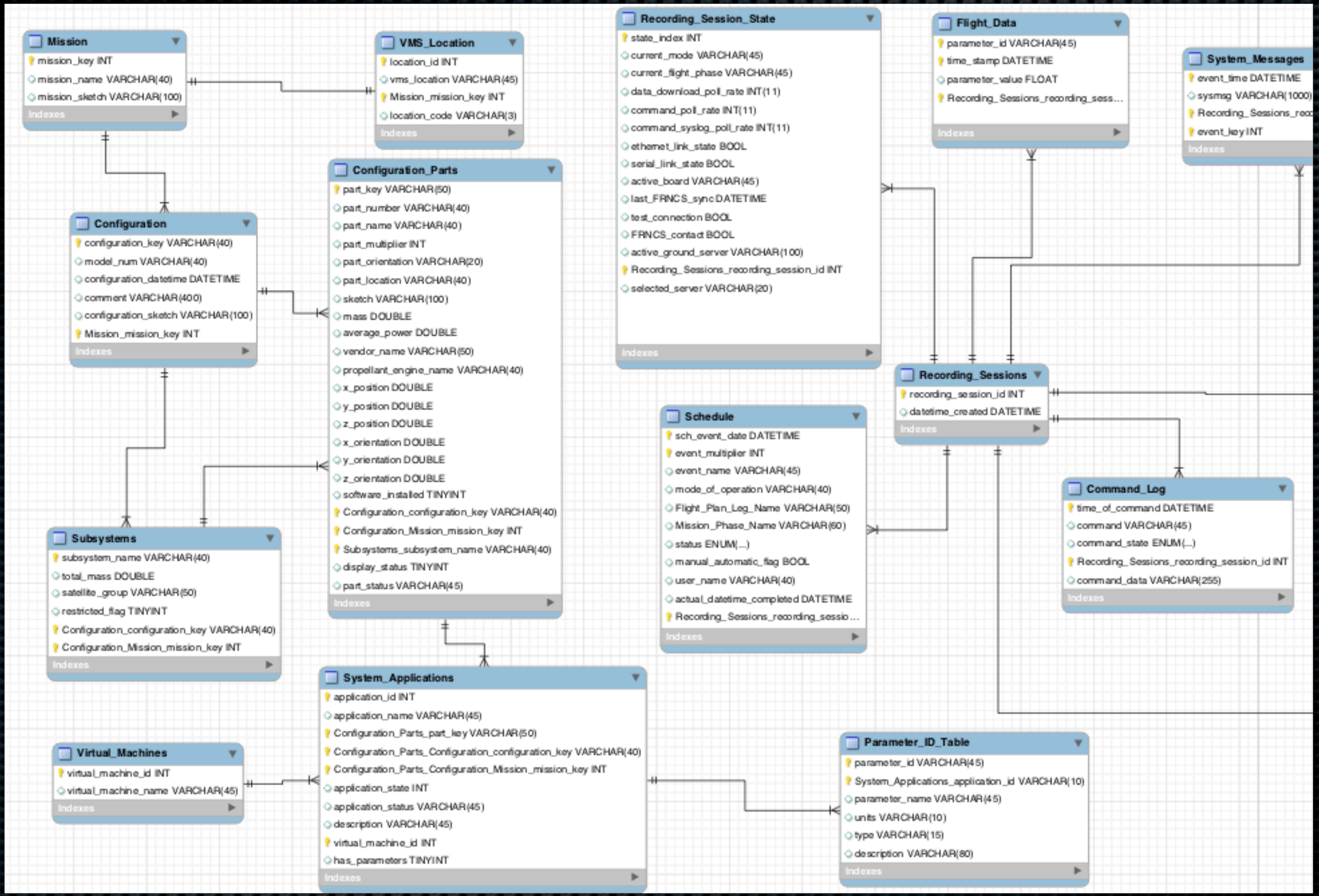
- MCP 1.0
- MCT 1.0

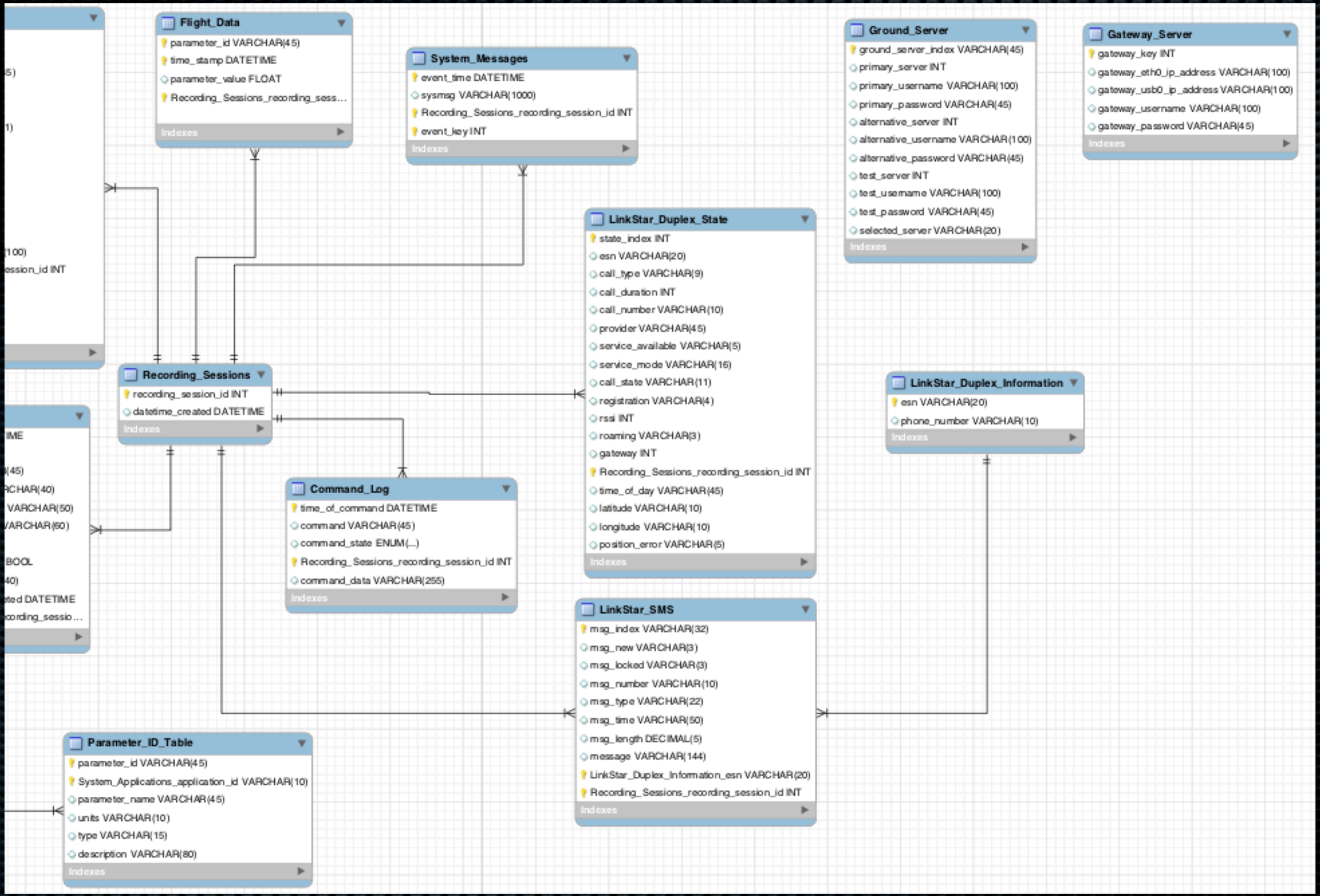
FRNCS

Flight computer



ARM-15, -8, -7
Intel Support


Mission
mission_key INT
mission_name VARCHAR(40)
mission_sketch VARCHAR(100)
Indexes
VMS_Location
location_id INT
vms_location VARCHAR(45)
Mission_mission_key INT
location_code VARCHAR(3)
Indexes
Recording_Session_State
state_index INT
current_mode VARCHAR(45)
current_flight_phase VARCHAR(45)
data_download_poll_rate INT(11)
command_poll_rate INT(11)
command_syslog_poll_rate INT(11)
ethernet_link_state BOOL
serial_link_state BOOL
active_board VARCHAR(45)
last_FRNCS_sync DATETIME
test_connection BOOL
FRNCS_contact BOOL
active_ground_server VARCHAR(100)
Recording_Sessions_recording_session_id INT
selected_server VARCHAR(20)
Indexes
Flight_Data
parameter_id VARCHAR(45)
time_stamp DATETIME
parameter_value FLOAT
Recording_Sessions_recording_sess...
Indexes
System_Messages
event_time DATETIME
sysmsg VARCHAR(1000)
Recording_Sessions_rec
event_key INT
Indexes
Configuration
configuration_key VARCHAR(40)
model_num VARCHAR(40)
configuration_datetime DATETIME
comment VARCHAR(400)
configuration_sketch VARCHAR(100)
Mission_mission_key INT
Indexes
Configuration_Parts
part_key VARCHAR(50)
part_number VARCHAR(40)
part_name VARCHAR(40)
part_multiplier INT
part_orientation VARCHAR(20)
part_location VARCHAR(40)
sketch VARCHAR(100)
mass DOUBLE
average_power DOUBLE
vendor_name VARCHAR(50)
propellant_engine_name VARCHAR(40)
x_position DOUBLE
y_position DOUBLE
z_position DOUBLE
x_orientation DOUBLE
y_orientation DOUBLE
z_orientation DOUBLE
software_installed TINYINT
Configuration_configuration_key VARCHAR(40)
Configuration_Mission_mission_key INT
Subsystems_subsystem_name VARCHAR(40)
display_status TINYINT
part_status VARCHAR(45)
Indexes
Recording_Sessions
recording_session_id INT
datetime_created DATETIME
Indexes
Schedule
sch_event_date DATETIME
event_multiplier INT
event_name VARCHAR(45)
mode_of_operation VARCHAR(40)
Flight_Plan_Leg_Name VARCHAR(50)
Mission_Phase_Name VARCHAR(60)
status ENUM(...)
manual_automatic_flag BOOL
user_name VARCHAR(40)
actual_datetime_completed DATETIME
Recording_Sessions_recording_sessio ...
Indexes
Command_Log
time_of_command DATETIME
command VARCHAR(45)
command_state ENUM(...)
Recording_Sessions_recording_session_id INT
command_data VARCHAR(255)
Indexes
Subsystems
subsystem_name VARCHAR(40)
total_mass DOUBLE
satellite_group VARCHAR(50)
restricted_flag TINYINT
Configuration_configuration_key VARCHAR(40)
Configuration_Mission_mission_key INT
Indexes
System_Applications
application_id INT
application_name VARCHAR(45)
Configuration_Parts_part_key VARCHAR(50)
Configuration_Parts_Configuration_configuration_key VARCHAR(40)
Configuration_Parts_Configuration_Mission_mission_key INT
application_state INT
application_status VARCHAR(45)
description VARCHAR(45)
virtual_machine_id INT
has_parameters TINYINT
Indexes
Virtual_Machines
virtual_machine_id INT
virtual_machine_name VARCHAR(45)
Indexes
Parameter_ID_Table
parameter_id VARCHAR(45)
System_Applications_application_id VARCHAR(10)
parameter_name VARCHAR(45)
units VARCHAR(10)
type VARCHAR(15)
description VARCHAR(80)
Indexes


Flight_Data
parameter_id VARCHAR(45)
time_stamp DATETIME
parameter_value FLOAT
Recording_Sessions_recording_sess...
Indexes
System_Messages
event_time DATETIME
sysmsg VARCHAR(1000)
Recording_Sessions_recording_session_id INT
event_key INT
Indexes
Ground_Server
ground_server_index VARCHAR(45)
primary_server INT
primary_username VARCHAR(100)
primary_password VARCHAR(45)
alternative_server INT
alternative_username VARCHAR(100)
alternative_password VARCHAR(45)
test_server INT
test_username VARCHAR(100)
test_password VARCHAR(45)
selected_server VARCHAR(20)
Indexes
Gateway_Server
gateway_key INT
gateway_eth0_ip_address VARCHAR(100)
gateway_usb0_ip_address VARCHAR(100)
gateway_username VARCHAR(100)
gateway_password VARCHAR(45)
Indexes
LinkStar_Duplex_State
state_index INT
esn VARCHAR(20)
call_type VARCHAR(9)
call_duration INT
call_number VARCHAR(10)
provider VARCHAR(45)
service_available VARCHAR(5)
service_mode VARCHAR(16)
call_state VARCHAR(11)
registration VARCHAR(4)
rssi INT
roaming VARCHAR(3)
gateway INT
Recording_Sessions_recording_session_id INT
time_of_day VARCHAR(45)
latitude VARCHAR(10)
longitude VARCHAR(10)
position_error VARCHAR(5)
Indexes
LinkStar_Duplex_Information
esn VARCHAR(20)
phone_number VARCHAR(10)
Indexes
Recording_Sessions
recording_session_id INT
datetime_created DATETIME
Indexes
Command_Log
time_of_command DATETIME
command VARCHAR(45)
command_state ENUM(...)
Recording_Sessions_recording_session_id INT
command_data VARCHAR(255)
Indexes
LinkStar_SMS
msg_index VARCHAR(32)
msg_new VARCHAR(3)
msg_locked VARCHAR(3)
msg_number VARCHAR(10)
msg_type VARCHAR(22)
msg_time VARCHAR(50)
msg_length DECIMAL(5)
message VARCHAR(144)
LinkStar_Duplex_Information_esn VARCHAR(20)
Recording_Sessions_recording_session_id INT
Indexes
Parameter_ID_Table
parameter_id VARCHAR(45)
System_Applications_application_id VARCHAR(10)
parameter_name VARCHAR(45)
units VARCHAR(10)
type VARCHAR(15)
description VARCHAR(80)
Indexes

Database Command Handling

localhost ▸ stepSATdb_Flight ▸ Command_Log

Browse | Structure | SQL | Search | Insert | Expor

#	Column	Type
1	time_of_command	datetime
2	command	varchar(45)
3	command_state	enum('Pending', 'FAIL', 'Success')
4	Recording_Sessions_recording_session_id	int(11)
5	command_data	varchar(255)

time_of_command	command	command_state	Recording_Sessions_recording_session_id	command_data
2014-11-13 00:00:00	ADD_VMAPP	Success	25	1
2014-11-14 00:00:00	ADD_VMAPP	Success	25	2
2014-11-16 00:00:00	ADD_VMAPP	Success	25	3
2014-11-14 18:27:33	REMOVE_VMAPP	Success	25	1
2014-11-14 11:17:12	ADD_VMAPP	Pending	24	3
2014-11-18 21:24:43	ADD_VMAPP	Success	25	4

Communications

QuickSAT/VMS - Multiple Options

- S-Band radios
- Amateur Radios
- Laser based radios
- “Newly invented” radios
- *LinkStar*...

LinkStar Product Features

- Almost anytime, anywhere satellite TT&C
- Estimated +70% orbital coverage for Duplex based radios; over 95% for Simplex based radio!
- Common FCC Satellite-to-Satellite License
- No Amateur bands
- Radio astronomy interference was eliminated by limiting the GlobalStar units to operate at 1616.25 MHz with a bandwidth of +/- 1.25 MHz
- No satellite to ground license required

Globalstar Be Heard.

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LinkStar Product Features

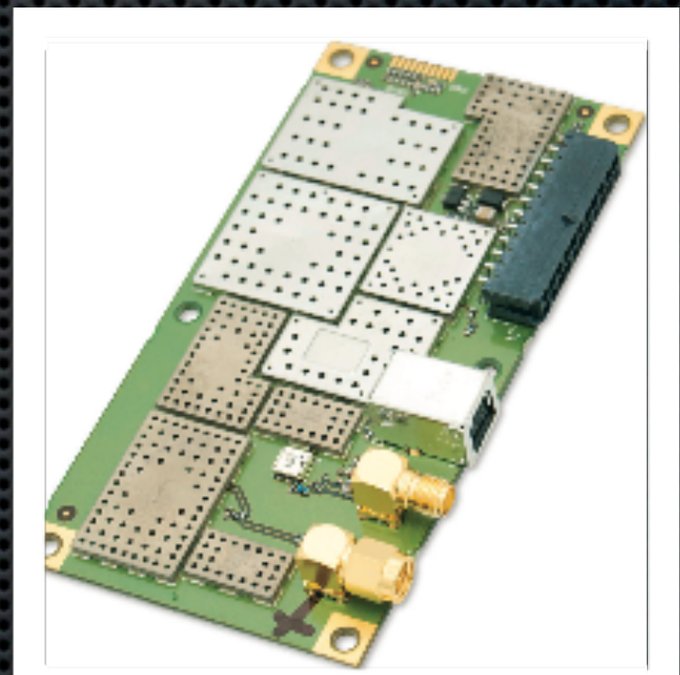
- No deployables
  - 2 cm x 2 cm patch for simplex
  - 2.5 cm diameter circular patch for duplex
- Rapid acquisition - simplex beacons within 15 seconds
- Data rates
  - 9600 kbps maximum
  - *LinkStar* can compliment traditional high speed radios
  - *LinkStar* can serve as a primary radio depending mission data requirements.

Globalstar Be Heard.

sci_Zone, Inc.
www.quick-sat.com

LinkStar Product Features

- Ground station over Internet Protocol (IP)
  - *Access your spacecraft from anywhere!*
- Piggy-backs on established 2 billion dollar network
- Low Cost
  - No Ground Station
- No tracking
- Proven system



Operating Frequencies	Transmit: 1610 MHz – 1626.5 MHz Receive: 2483.5 MHz – 2500 MHz
Maximum transmit power	+31dBm EIRP (passive antenna), +34 dBm (active antenna)
DC input voltage	+4.7V to 5.1V

Power Consumption @5VDC input (estimated)

State	Min	Typical	Max	Units
Shutdown	0.0	0.65	1.0	mW
Standby	0.5	0.5	1.1	W
Transmit	2.2	3.65	5.0	W

Globalstar Be Heard.

sci_Zone, Inc.

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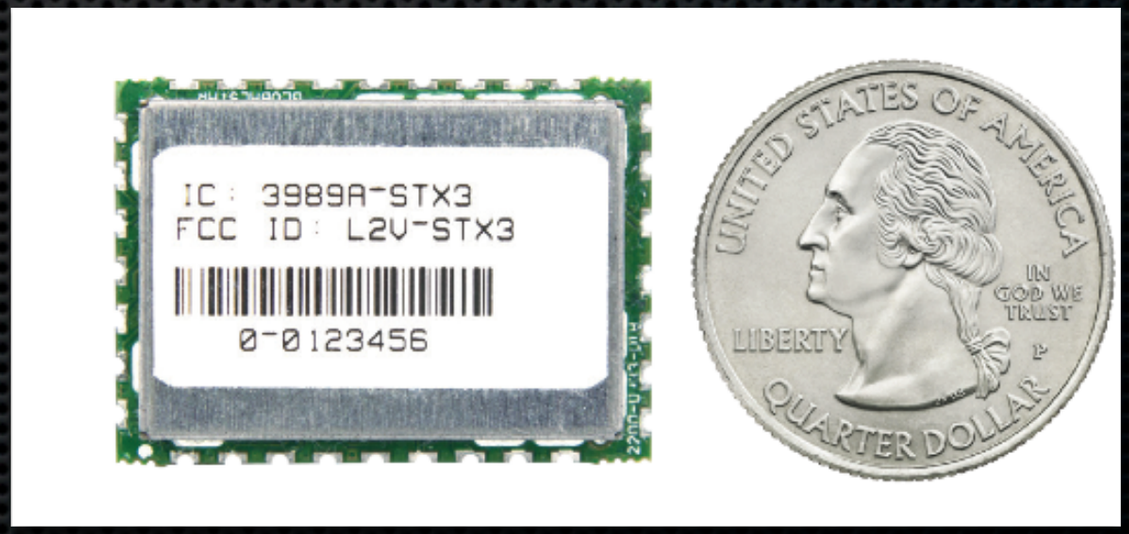
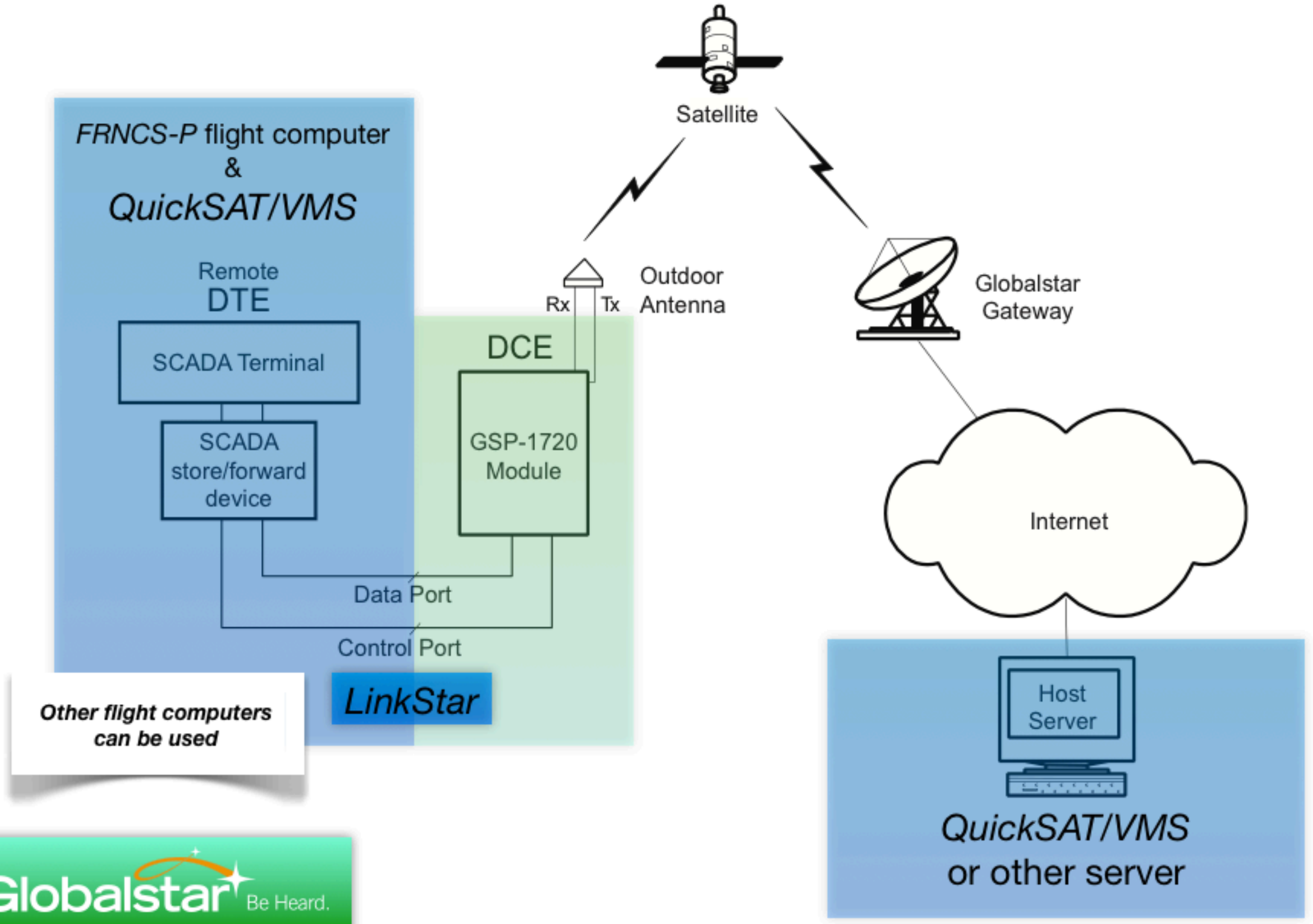
LinkStar-STX3
Simplex Gen 3 Features

- Small form factor
- Power
  - 350 mW Tx power
- Dimensions
  - 28.7mm x 20.57mm x 4.13mm
- Electrical
  - Accepts 3.3 V to 12 V
  - TTL Data Protocol
- Near Global Coverage!



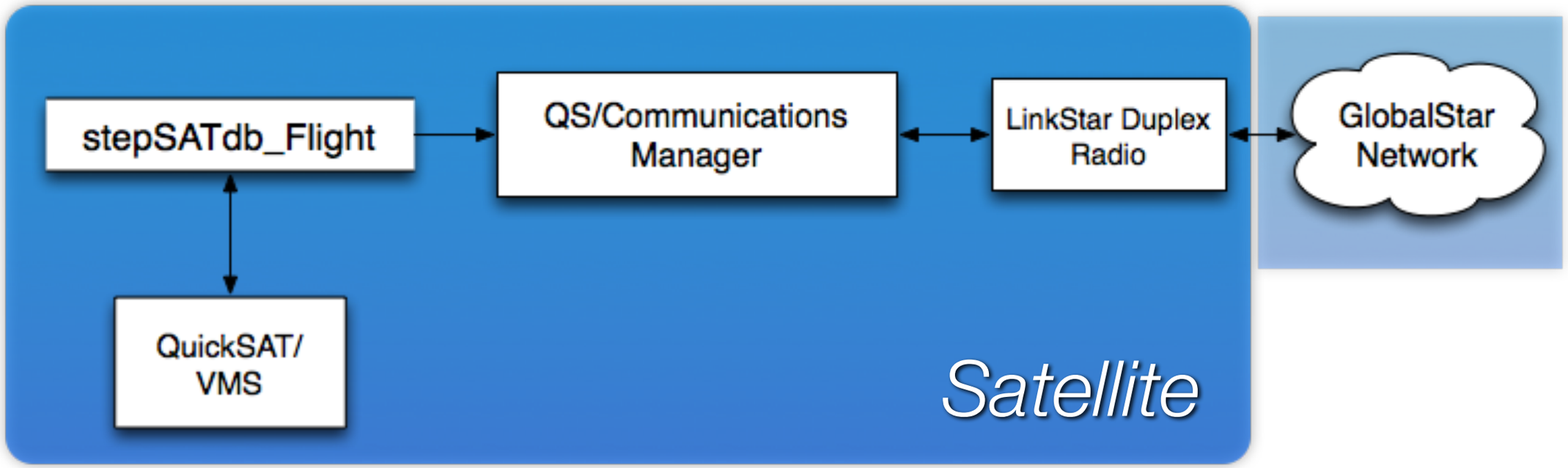
Globalstar Be Heard.

Baseline Communications Scheme with LinkStar

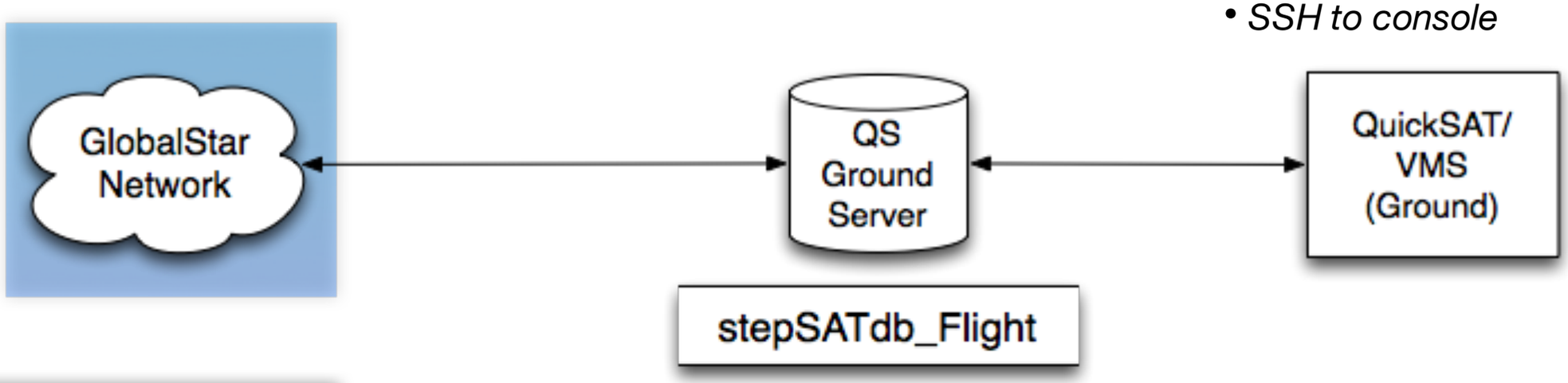


Globalstar Be Heard.

Satellite to Ground

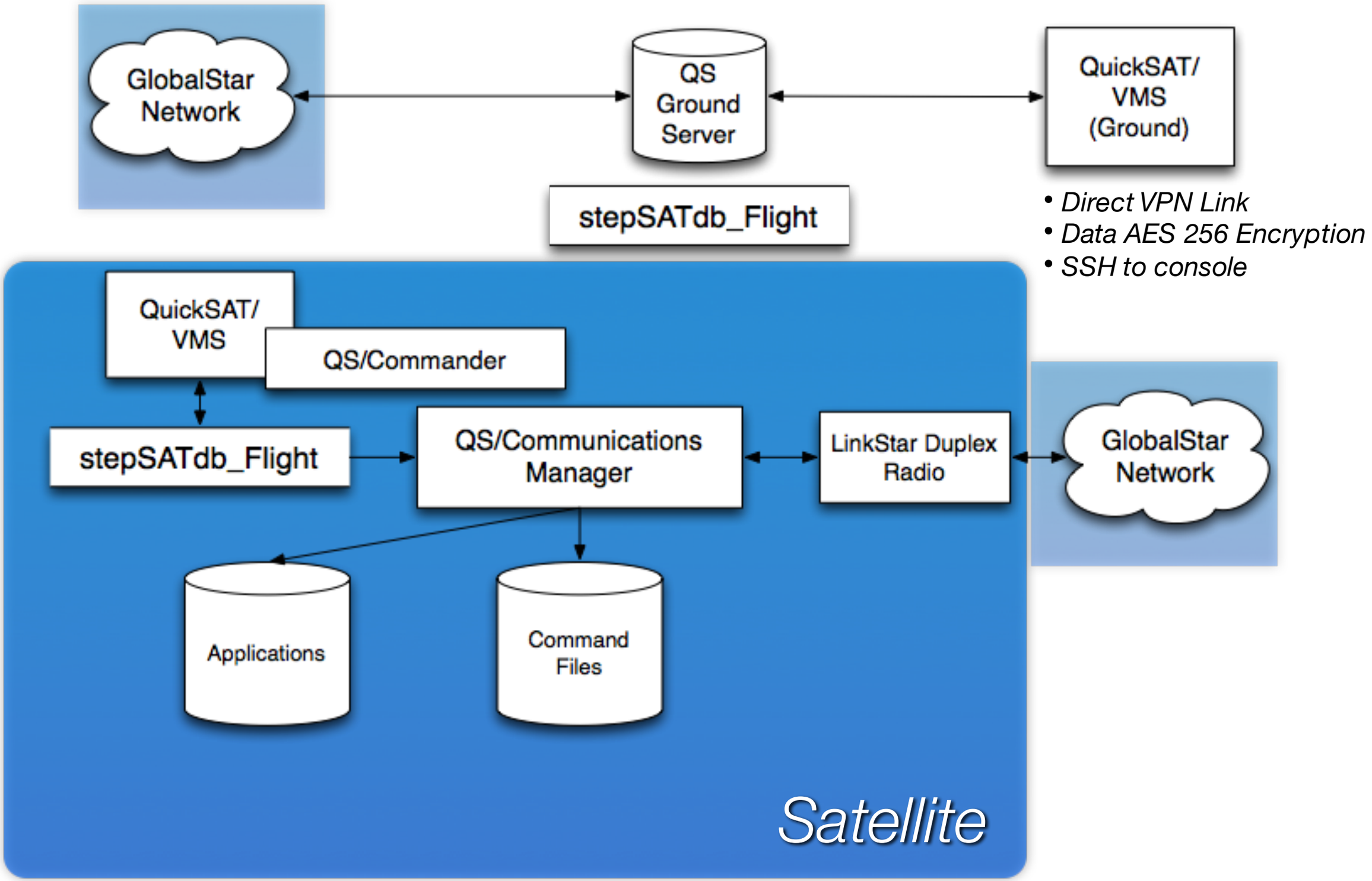


- *Direct VPN Link*
- *Data AES 256 Encryption*
- *SSH to console*



Globalstar Be Heard.

Ground to Satellite



- *Direct VPN Link*
- *Data AES 256 Encryption*
- *SSH to console*

QS/VMS
Vehicle Management System

Identifier: FRNCS-P/SHARC | Sessions | Update Location | Admin | Logout

Last DB Capture: 04/18/2015 @ 02:15:43
Current Recording Session: 72
Mission Phase: Operating Mode
Mode of Operation: Mission Science/Operations
Current VMS Command: *No Commands Pending*

GSTAR USA
Last Sync with FRNCS: 04/18/2015 @ 02:15:43

Configuration | Mission Operations | Live Parameter View | FRNCS Maintenance | Schedule | Server

FRNCS-P | Space Vehicle Profile

FRNCS Virtual Machines and Software

CSV | Excel

Search:

ID	Name	Status	State Code	State
VM1: Domain 1				
1	prime	GATEWAY Storage	80	FRNCS Stora
VM2: Domain 2				
2	prime	GATEWAY Storage	80	FRNCS Stora
VM3: Domain 3				
3	sine	GATEWAY Storage	80	FRNCS Stora
VM4: Domain 4				

Showing 1 to 5 of 5 entries

Parameters
for the application "prime"

CSV | Excel

Search:

ID	Parameter Name	Units	Type	Description
1	Prime Number	n/a	INTEGER	Calculated prime value for the give

FRNCS-P | Space Vehicle Profile

Space Vehicle Profile

SHARC Mission

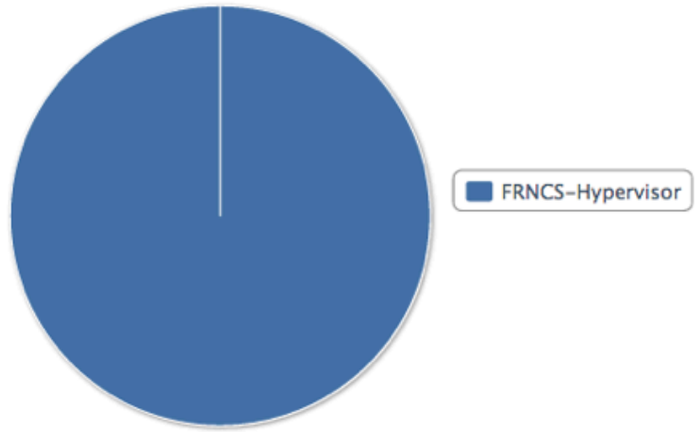
Configuration:	Rev 4.0 SHARC
Model Number:	Version 4.0
Date/Time:	2014-10-09 01:42:39
Comments:	SHARC is a 5U cubesat to be deployed from the ISS

Search:

Subsystem	Subsystem Mass (kg)
FRNCS-Hypervisor	0.39

Showing 1 to 1 of 1 entries

Subsystem Mass Summary Chart



Satellite Mass, Dry (kg):	0.39
Mass Propellants (kg):	0.00
Satellite Mass (Dry + Propellants, kg):	0.39

Select all | Deselect all | CSV | Excel | PDF | Copy

Search:

Part Name	Part Number	Multiplier	Vendor	Mass	Avg Power (Watts)	Part Key
BeagleBone Black, RevC	BeagleBoneBlackRevC00001	1		0.03968	2.3	BeagleBoneBlackRevC000011
Cubieboard3 - Cubietruck	800024001	1	sci_Zone Inc	0.1	5	8000240011
FRNCS-P Bracket	SHARCFRNCSBracket-01	1	AFRL	0.2	0	SHARCFRNCSBracket-011
Global Star Duplex Antenna X2	duplexantennaX2	1	sci_Zone Inc	0	0	duplexantennaX21
LinkStar Duplex Radio	LinkStar-0001-v00100001	1	sci_Zone Inc	0.05	2	LinkStar-0001-v001000011

QS/VMS

Vehicle Management System

Identifier: FRNCS-P/SHARC | Sessions | Update Location | Admin | Logout

Last DB Capture: 04/18/2015 @ 02:15:43
Current Recording Session: 72
Mission Phase: Operating Mode
Mode of Operation: Mission Science/Operations
Current VMS Command: *No Commands Pending*

GSTAR USA
Last Sync with FRNCS: 04/18/2015 @ 02:15:43

figuration | Mission Operations | Live Parameter View | FRNCS Maintenance | Schedule | Server

NCS-P | Space Vehicle Profile

RNCS Virtual Machines and Software

CSV | Excel | PDF | Copy

Search:

Name	Status	State Code	State
Domain 1			
prime	GATEWAY Storage	80	FRNCS Storage
Domain 2			
prime	GATEWAY Storage	80	FRNCS Storage
Domain 3			

Hide Parameters

Upload Gateway -> Host

Delete from Gateway

Operations | Support | LinkStar | Recording Sessions

Ethernet Comm Status: Link Active
Serial Line Status: Link Disabled
Active Board: Host_1

FRNCS Software Status

Search:

ID	Name	Status	State Code	State
VM1: Domain 1				
1	prime	GATEWAY Storage	80	FRNCS Storage
VM2: Domain 2				
2	prime	GATEWAY Storage	80	FRNCS Storage
VM3: Domain 3				
3	sine	GATEWAY Storage	80	FRNCS Storage
VM4: Domain 4				

Showing 1 to 5 of 5 entries

Schedule

CSV | Excel | PDF | Copy

Search:

Event Date/Time (UTC)	Multiplier	Event Name	Status	User	Date/Time Completed (UTC)	Mode of Operation	Flight Leg	Mission Phase
2015-08-10 08:15:40	1	TEST	Pending	Admin	-	Mission Science/Operations	Primary	Operating Mode

Schedule

CSV Excel PDF Copy

Search:

Event Date/Time (UTC)	Multiplier	Event Name	Status	User	Date/Time Completed (UTC)	Mode of Operation	Flight Leg	Mission Phase
2015-08-10 08:15:40	1	TEST	Pending	Admin	-	Mission Science/Operations	Primary	Operating Mode

Showing 1 to 1 of 1 entries

Command Log

CSV Excel PDF Copy

Search:

Time of Command (UTC)	Command	Command State	Command Data
2014-04-29 02:16:33	REMOVE_VMAPP	Success	1
2015-02-17 21:43:57	REMOVE_VMAPP	Success	1
2015-02-17 21:55:58	REMOVE_VMAPP	Success	2
2015-11-18 20:00:14	REMOVE_VMAPP	Success	2
2015-11-18 20:01:27	ADD_VMAPP	Success	1
2015-11-19 09:39:46	ADD_VMAPP	Success	3

Showing 1 to 31 of 31 entries

System Message Log

CSV Excel PDF Copy

Search:

System Message Time (UTC)	System Message
2014-04-23 20:23:20	Success - VM/App "prime_test_app00001" installed
2014-04-23 20:23:20	Command Success
2014-04-23 20:25:24	Success - VM/App "cosine_test_app00001" installed
2014-04-23 20:25:24	Command Success

QS/VMS

Vehicle Management System

Identifier: FRNCS-P/SHARC | Sessions | Update Location | Admin | Logout

Last DB Capture: 04/18/2015 @ 02:14:53
Current Recording Session: 72
Mission Phase: Operating Mode
Mode of Operation: Mission Science/Operations
Current VMS Command: *No Commands Pending*

GSTAR USA
Last Sync with FRNCS: 04/18/2015 @ 02:14:53

Configuration | Mission Operations | Live Parameter View | FRNCS Maintenance | Schedule | Server

Operations | Support | LinkStar | Recording Sessions

LinkStar Duplex Status

Phone Number: *2542045633*
esn: *11601206706*
Call Type:
Call Duration: 0
Call Number:
Provider: GSTAR USA
Service Available: YES
Service Mode: GLOBALSTAR
Call State: IDLE
Registration: YES
RSSI: 4
Roaming: NO
Gateway: 11

LinkStar Duplex Location

Time of Day: *2014:355 00:44:20*
Latitude (N): 035 Deg 16' 50"
Longitude (W): 106 Deg 37' 51"
Position Error: < 10 km

LinkStar Duplex SMS Messages (received)

No SMS Messges Exist

QS/VMS

Vehicle Management System

Admin

Mode: SIMULATION | Maintenance Mode | Sessions | Update Location | Logout

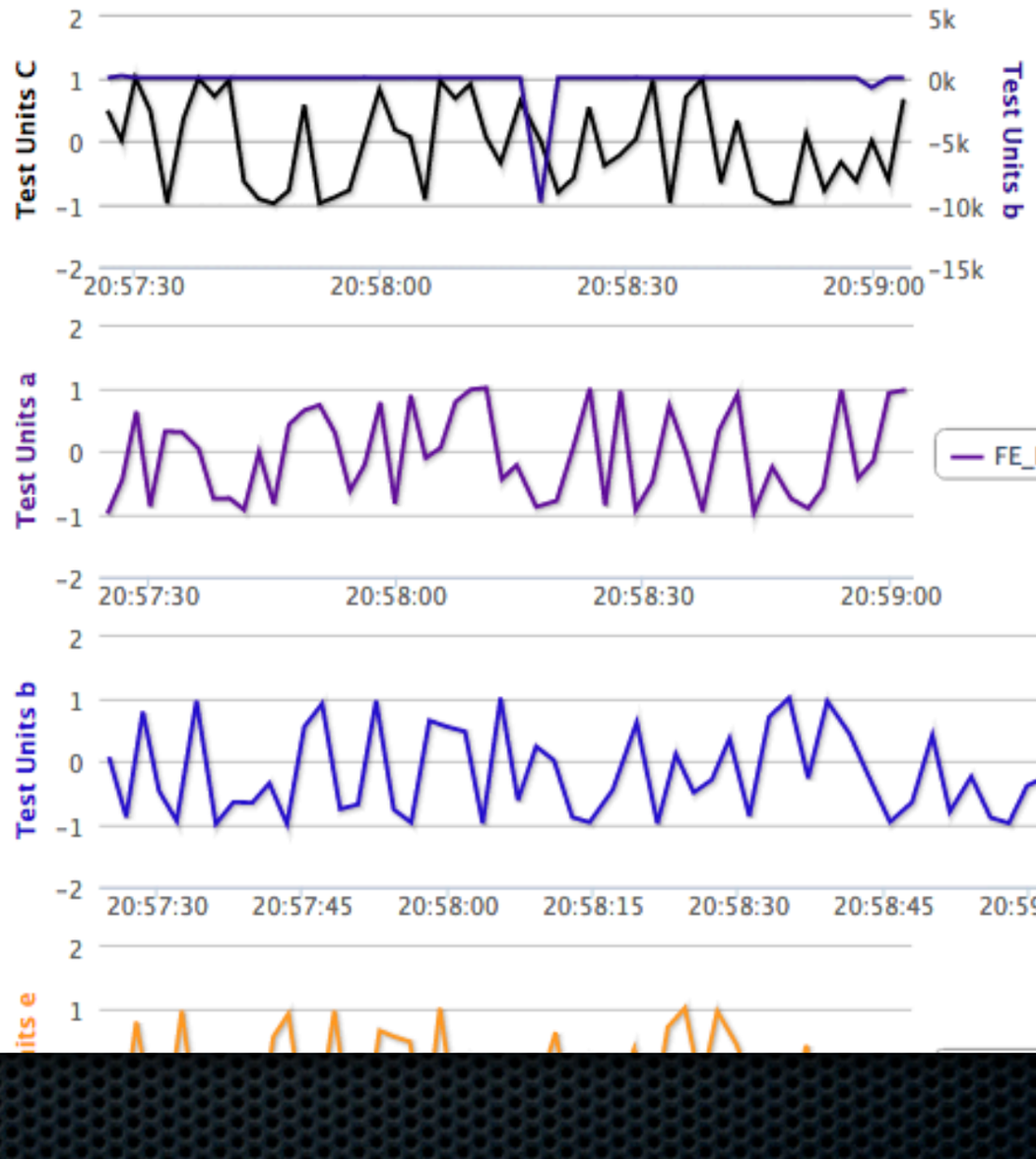
SD Card : | Percent Progress: null

USB: Downloading

Ground Comms: Completed | Percent Progress: 0

Configuration | Ground Communications | USB | BIT | Events | Download » | Upload » | Add Ons...DPD

Parameter Lists | Select Parameters | Data Display | Plot | Group



Selected Parameters

Parameter List:
AnotherTest

Plot Selected Parameters

Delete Selected Parameters

Save List | Update List

Select all | Deselect all

Search:

Parameter Name

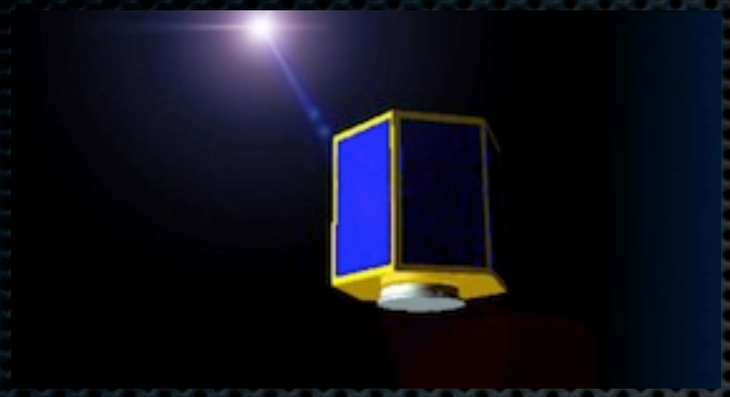
- *No Group Assigned*
- FC_BAT_TEMP FC_BAT_TI
- FE_BAT_DISC_1
- "47_1_0_1398"
- "19_1_0_186"
- "19_6_0_186"
- "19_1_0_185"
- "19_6_0_185"
- Batteries
- RM_BAT_TEMP
- 19_6_0_183
- Extra Systems

Road Map To Flight Heritage

- Enhanced *QuickSAT/VMS* with *LinkStar* Support: Spring 2015
- *BeagleSpace* on GitHub*:* August 2015
- *CubieSpace* on GitHub: August 2015
- *QuickSAT/VMS* on GitHub: September 2015
- *RADSat*: Fall 2015
- *EarthScan*: Fall 2016

QuickSAT

Take your satellite from idea to flight!



QuickSAT/Designer

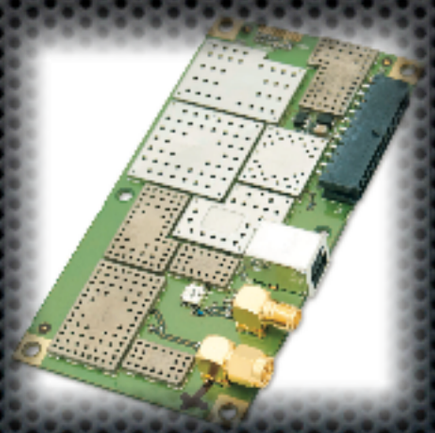
Design and Mission Planning from idea to flight!

QuickSAT/Xen

Security, Reliability and Software Rad-Hardening!

QuickSAT/VMS

Talk to your satellite!



LinkStar

Communications for the Rest of us!

FRNCS

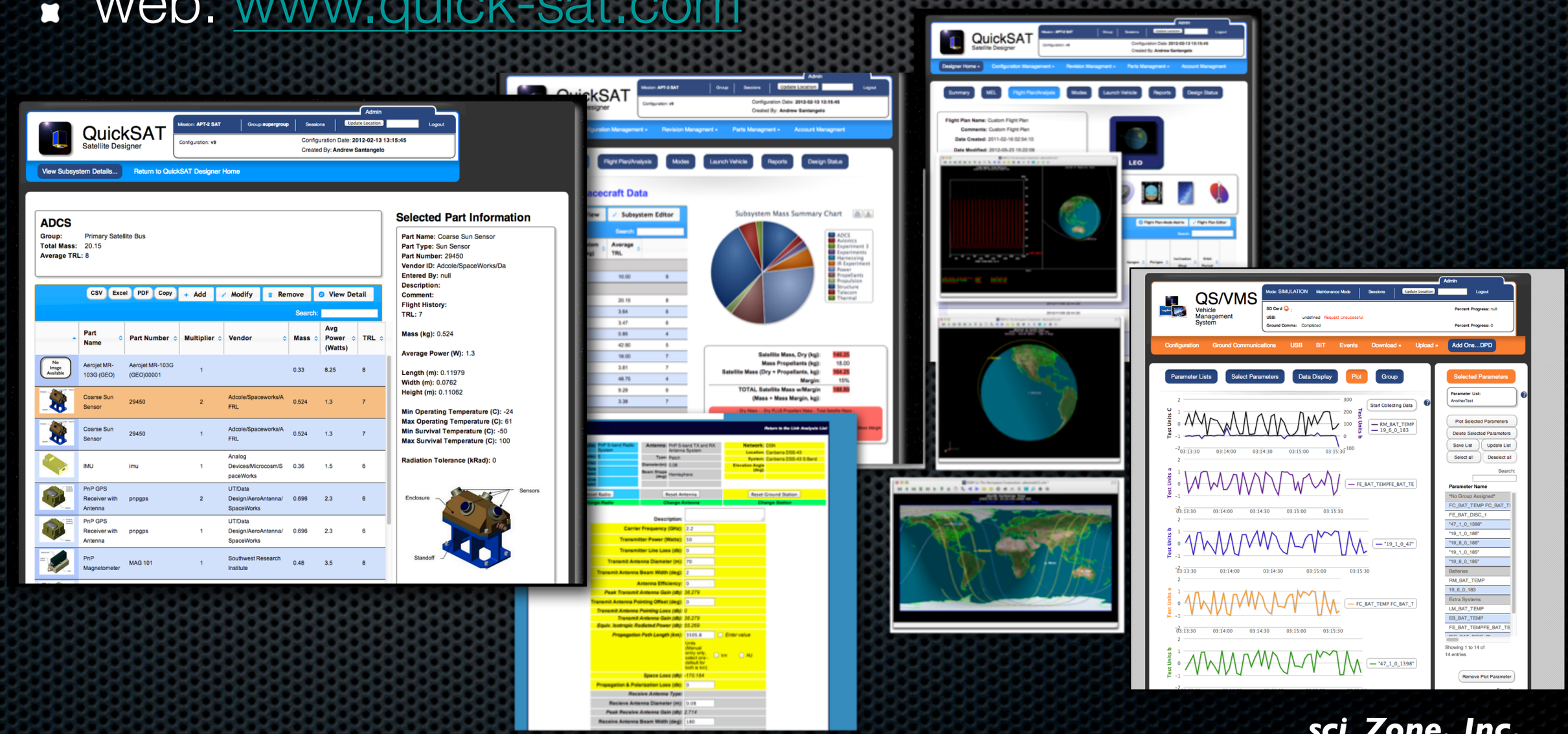
ARM Computing for the Future!

sci_Zone, Inc.

www.quick-sat.com

Next STEP - Join the Fun!

- email: andrew_santangelo@sci-zone.com
- web: www.quick-sat.com



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