<u>Tiger Innovation's Integrated Test Rack</u>

The Integrated Test Rack (ITR) is a complete EGSE test suite for command and control of spacecraft and other complicated systems. The ITR is a turn-key integration and test solution with capabilities proven through rigorous spacecraft I&T campaigns. Tiger Innovations EGSE racks have been used on the HENEX program, STPSat-1 mission, and are currently being built to support the STP-SIV mission with delivery in Fall 2007.

The ITR is a modular system and can be configured to meet the needs of a wide range of programs. Typical hardware choices include the Tiger Innovation's Frame Sync Box, Control Box, and Solar Array Simulator (SAS), as well as COTS components to provide GPS time synchronization, power supplies, and an UPS. The ITR system generally requires no external components to interface to an RF system (either BitSync/RF Uplink or COMSEC gear). Control and configuration of the ITR can be accomplished using either front panel menu driven control or through the StreamLINK software package. StreamLINK provides the command and telemetry interface with both the ITR as well as the spacecraft the ITR is controlling. StreamLINK's commanding and telemetry decommutation capabilities are database driven and can quickly and seamlessly incorporate multiple databases in support of many different missions.

When the system is utilized as a whole, it helps reduce overall program risk, since all of the development and test uses the same system as the on-orbit operations. Additionally, it provides the ability to significantly automate large sections of the integration and test (especially environmental test) portions of the development cycle, which reduces labor cost, and increases testing fidelity (thereby reducing technical risk).

The ITR system provides a proven, cost-effective, and adaptable solution for complete spacecraft development campaigns. It is uniquely capable of inexpensively keeping pace with the rapid spacecraft development cycles present in today's responsive space environment.

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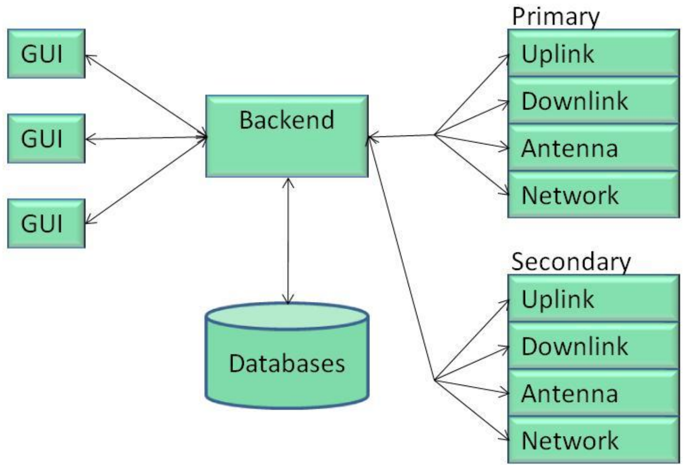
STREAMLINK CONTROL SYSTEM

Tiger Innovations' StreamLINK system is a complete space vehicle planning and control tool for use with on-orbit satellites as well as in the integration and test environment. StreamLINK is designed as a distributed control system with three topological layers comprising a given system: User Interface, Backend Control, and Device Interface. The layers communicate with each other via TCP/IP sockets and can exist in separate physical locations. StreamLINK uses databases to define commanding, and telemetry de-commutation and display (including derived telemetry points). Other features include real-time plotting of telemetry items, a scripting tool for development of automated command sequences and tests, and a playback function used to view stored telemetry files. StreamLINK has mission-planning tools to support range data processing, calculating pass times, and generating antenna pointing angles.

The graphical user interface provides an interface to display telemetry in engineering units (EU), send individual commands to the spacecraft, system devices, and execution control of scripts. Each user has control over nearly all facets of the display, including per-user customized displays, graphs, and tables.

The backend control provides a central repository for all system information. It provides access to telemetry, commanding, and display databases. Telemetered information is converted from raw counts to engineering units and stored in the internal databases. The backend also provides command/script execution; including all math and telemetry functionality.

The device interfaces provide the specific software interface to various system devices, such as the spacecraft downlink, spacecraft uplink, uninterruptible power supply, solar array simulator, frame synchronizer, etc. The external physical interfaces are converted to/from internal TCP/IP based formats at the individual device interface.

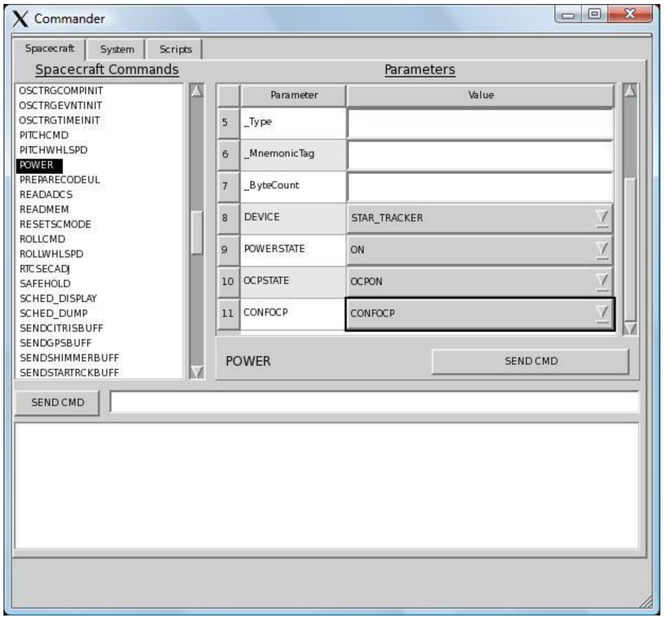


StreamLINK Architecture

The StreamLINK system currently provides basic CCSDS compliance for uplink and downlink data frames, in addition to fully custom interfaces. The CCSDS Channel Access Data Units are parsed for data information (VCDU, M_PDU, and CP_PDU units), separating out and properly disseminating the virtual channels. These channels are defined within the program-specific modules and are easily changed (via source code) for each spacecraft. The telemetry decommutation formats and command formulations are all database driven and require no modification to change from spacecraft to spacecraft. The specific communication protocol is implemented in a very modular fashion, limiting the impact and development time/cost of supporting additional missions.

COMMAND PROCESSING

Commands can be sent both manually or through the use of predefined command scripts. Manual commanding is accomplished using the commander window. All spacecraft commands are loaded from the database and presented using command mnemonics. When a command is selected, its parameters are displayed in the commander window where each can be configured. Command scripts send commands to the backend as the corresponding lines of code are executed.



StreamLINK Commander

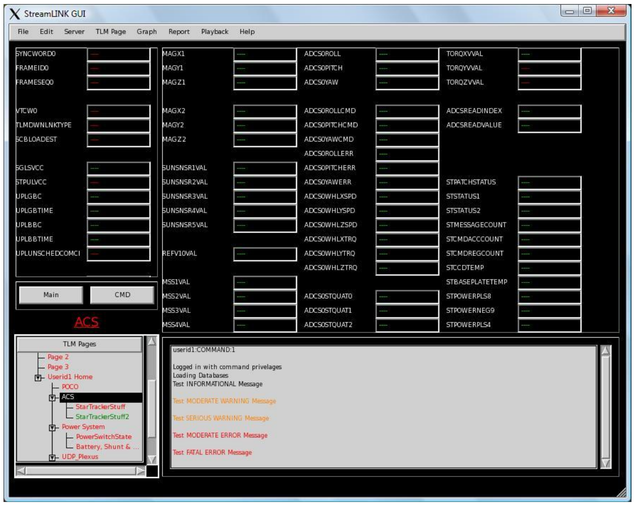
Once commands are properly selected and released to the spacecraft, they are formatted (based upon the command database and any program-specific requirements) and released to the hardware. The hardware performs any level-shifting and physical layer formats required to present the data to upstream commanding slices (COMSEC/RF Modulation: generally in ternary or synchronous serial format, but nearly any customer-specific format can be accommodated).

SEQUENCING

During a real-time communication event, command sequencing is accomplished through the use of StreamLINK's command scripts. StreamLINK scripts are written using the Tcl language, which provides simple but highly capable programming functions. Built-in functions allow the user to autonomously send commands to the ground equipment and monitor telemetry (both spacecraft and ground equipment) to ensure the accuracy and repeatability of command sequences. Command uploads are also created using StreamLINK's scripting language. Scheduled commands can be transmitted individually or grouped into block loads for transmission to the space vehicle as a single packet.

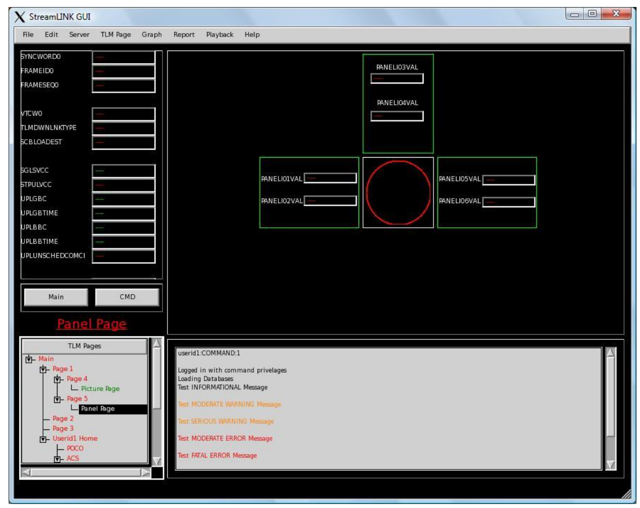
TELEMETRY PROCESSING AND DISPLAY

The StreamLINK system receives digital, binary data from the RF subsystem. The interface is standard and will work with most bit-syncs and COMSEC gear. Once the data is received, it enters the frame synchronizer, which extracts valid frames of data (indicated by proper header/sync bits, frame size, and CRC computation). Once the frames are extracted, they are time-tagged and sent, via Ethernet, to the StreamLINK backend.



StreamLINK Telemetry Display

All data packets are archived at the StreamLINK backend. The frames are then handled according to the spacecraft-specific processing requirements (e.g. CCSDS packet assembly and channelization or proprietary packet handling algorithms). The real-time telemetry packets are forwarded to the backend database for telemetry update. The then-current telemetry values are forwarded to the front-end GUIs for user display twice per second (this is the default; the rate is configurable by the user).



TLM Linked Graphics

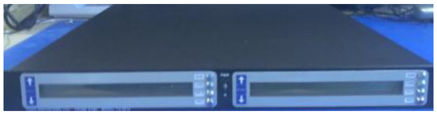
Telemetry data is presented to the user on telemetry pages, graphs, or tabular reports. Individual telemetry pages are organized in a configurable hierarchical tree. Selecting an item from the tree displays it in the main telemetry window. Limit checking is performed by the backend and violations are sent to the GUI. Points are displayed in green if they are functioning properly and in yellow or red if they are outside limits set in the telemetry database. If a point is outside of its limits, it will change the status of its parent telemetry page to the same color so that the user can quickly see which pages contain telemetry items that are out of limits. Limit violation reports are also created for every pass, listing every point that was out of limits for the duration of the pass. In addition to standard telemetry displays, users can create graphics and insert images on TLM pages. Each graphic item can be linked to a telemetry point so its color changes based on the underlying value. This capability is a powerful tool for determining system health and status at a glance.

DATA MANAGEMENT AND ARCHIVING

All telemetry data received from the space vehicle is logged on the backend as it is recieved. Post pass processing separates the data into real-time state of health, stored state of health (back-orbit data), and payload specific data files for dissemination to the various users. StreamLINK provides GUI based telemetry processing tools for generating plots and reports for archived telemetry data. In addition to plotting stored telemetry, StreamLINK can playback both real-time and back-orbit state of health data for anomaly investigations or trending analysis.

ITR HARDWARE

FRAME SYNCHRONIZATION



The Tiger Innovations Frame Synchronization Box (FS-201U) provides single or dual, fully independent frame syncs for use in telemetry processing. The FS-201U receives a serial bit stream, syncs on the frame, and executes CRC checking. The frame sync box time tags each frame reception with an accuracy of 1 microsecond. Data can be output over TCP/IP, synchronous, asynchronous, or customized RS-422 serial protocol. The frame sync is fully compatible with COMSEC interfaces such as the KI-17. The FS-201U is contained in a 1U, 19" rack mount case.

SPACECRAFT CONTROL BOX

The Tiger Innovations SC Control Box (CB-4UN) is configurable for each mission. The default configuration provides 16 power switches, 16 break-wire switches, 10 simulated loads, and digital command and telemetry control including a SGLS simulator. All switches and loads can be monitored and controlled through the front panel of the control box as well as through the StreamLINK software.

SOLAR ARRAY SIMULATOR

The Tiger Innovations SAS (TSAS-4UN) provides up to 16 individual solar array simulators. Each simulator is individually controllable for max-power current/voltage, short circuit current, and open circuit voltage. Additionally, each simulator has a PRTD simulator covering the range of –120C to +120C. The TSAS-4UN fully integrates with StreamLINK and can be controlled via the front panel or Ethernet.

GPS TIME SYNCHRONIZATION

The ITR can receive a real-time GPS signal and provide a 1 Hz tick for synchronization accurate to 1 micro-second.

POWER

The ITR can be configured with one or more 20 Amp power supplies to provide power to the spacecraft. Power supplies specifications vary based on mission requirements and inclusion of the SAS. The ITR includes an UPS backup power system with a capacity sized to meet mission requirements.

COMPUTERS AND NETWORK ACCESS

Each ITR is delivered with two rack mounted Linux PCs (one for the frontend, one for the backend) with all necessary software installed. In addition, a third computer can be added to supply RAID-5 Network Attached Storage. The ITR interfaces with an outside network through an external Ethernet connector. The external interface is DHCP controlled which allows the rack to be connected to the facility LAN. The LAN connects directly to the ITR through a firewall which is used to isolate the rack from the LAN. The firewall and all internal rack components are connected to a Gigabit Ethernet switch.

PERFORMANCE

The ITR utilizes Tiger Innovations' frame synchronizer that detects data framing patterns, checks overall packet CRC, and forwards data to the StreamLINK backend for further processing. There is a delay of 5-15ms from the end of the packet reception at the frame synchronizer to the start of processing by the StreamLINK backend. The last bit in the packet is time-tagged to GPS time at the frame synchronizer with sub-microsecond precision. The frame synchronizer accepts a GPS PPS signal to drive the time process. The frame synchronizer handles data rates from DC through 4Mbit/second in its current configuration. The data rate capability can be increased with some minor development.

Data packets are first archived at the StreamLINK backend. The frames are then handled according to the spacecraft-specific processing requirements (e.g. CCSDS packet assembly and channelization). The real-time telemetry packets are forwarded to the backend database for telemetry update. The now-current telemetry values are forwarded to the front-end GUIs for user display twice per second (this is the default; the rate is configurable by the user). The backend telemetry-processing throughput depends upon the packet structure and size; however, as a metric, a previous program with 1000 byte telemetry frames yielded a maximum throughput of approximately 2000 packets per second.

RECONFIGURABILITY

Our company philosophy is to develop systems in a very modular, generic fashion so that they can be easily re-used and re-configured. These are the underlying guidelines behind our StreamLINK control system. Command and Telemetry formats are completely database driven, with very extensive feature sets. We have a TCL-based command/scripting language allowing the easy development of simple to very-complex control scripts. Generally these scripts are used to perform various automated functions, allowing for very repeatable operational sequences or testing baselines.

Generally, each satellite program has a few items that are very program specific. We have designed StreamLINK to be highly modular, with each program having a small set of code to provide the specific "personality" (e.g. specific application commanding formats or payload data processing). These small modules are made up of a series of standard functions, which get called at specific points in the data processing. It is a very simple matter to make significant changes to the data communication protocols without the possibility of damaging anything in the core system functionality. This very process was used to implement the STPSAT-1 to STP-SIV mission-unique software in a matter of weeks.

There is no "glueware" required to operate the system – it is meant to be a stand-alone, end-to-end system. Our frame synchronization hardware interfaces directly to COMSEC or BITSYNC equipment (all of the input signal mappings and polarities are front-panel/Ethernet controllable). It handles all of the framing, CRC-checking, and conversion of the data stream to IP packets.

The remainder of the system processes the data in that format. Data can be distributed to the engineering community in various formats: TCP/IP socket, serial port, or data files.

There are many designed-in features to allow system extension. An example is the generic GPIB communication service: additional devices (and their control sequences) are described in an XML-like configuration file. The user can edit this file to add new (unforeseen) devices to the system. Since the system already has the infrastructure to control generic devices, integration of the new device into the system is complete after adding the device's control parameters to the configuration file. Additionally, although Tiger Innovations can assist with the addition of new equipment, the user can generally accomplish the addition without requiring our assistance, reducing overall cost.

AUTONOMOUS OPERATION

StreamLINK can autonomously configure the ground system for each selected contact, generating antenna pointing angles, pass times, and communication gear settings, as well as preparing to process and log telemetry data. Automated command sequences can be generated using StreamLINK scripts to perform normal operations such as command uploads, stored data downloads, and critical telemetry monitoring. Post pass telemetry processing can be configured to run automatically after every pass and generate predefined plots and reports. Using these capabilities, personnel requirements can be greatly reduced for normal spacecraft operations.

INITIAL COST

The ITR is delivered in a single 19-inch shock-mounted rack (height varies up to 32U depending upon the selected components), and includes all of the applicable/selected hardware (UPS, power supplies, GPS unit, computers, SC Control box, SAS, etc). The StreamLINK license is per backend (single spacecraft, infinite user license). The cost ranges from $50K to $950K for the integrated hardware and first year's license (depending upon equipment and options). Backend customization (for program-specific development) is billed on a T&M basis (2-6 man-months is a reasonable estimate). Yearly backend licenses are as low as $20K per year when purchased in multi-year increments. Lead time is dependent upon the amount of development required, but generally not less than 4-6 months, without an expedite fee (accelerated to as quickly as 3-4 weeks). Customers can also purchase less expensive systems for script development/testing. The license fees are dependent upon quantity, fidelity, and other factors.

OPERATIONAL COST

There is no operational support required. We offer on-site training classes, which should permit your own personnel to effectively administer the system, and handle most issues. Generally upgrades are handled on a Time-and-Materials basis; however, custom agreements can be tailored to just about any situation, in order to be the most cost-effective.

Systematic upgrades are not required. Licensing is handled on a per-installation basis (unlimited user). We have several different license terms available: yearly, per-mission, or multi-year with transition to yearly. We can certainly negotiate a license structure that is compatible with your program/budget constraints.

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Tiger Innovations, L.L.C. is a well-qualified, high technology, small business (within the SBA NAICS 336414 size standard) with a broad range of experience in specialty software/computer architecture design and implementation. Our experience ranges from hardware and software design and implementation for real-time embedded systems (spacecraft and long-range airborne communication and control processors) to custom software/COTS product integration for multiple workstations. Our primary focus is satellite systems and related support equipment. We have extensive experience with custom hardware, software, and communication protocol design and implementation. Our company philosophy is such that we view the entire project (design, development, documentation, and training) as equally important pieces, and we strive to provide the best possible product in all areas.

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