Ball Aerospace COSMOS Open Source Command and Control System

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ABSTRACT

Ball Aerospace COSMOS is a free and readily available open source command and control system for operations and test. It brings a set of functionality to the small sat community that has previously only been available in proprietary and expensive COTS solutions. A set of 15 applications provide automated procedures, realtime and offline telemetry display and graphing, logged data analysis and CSV extraction, limits monitoring, command and telemetry handbook creation, and binary file editing. COSMOS scripting offers the full power of the Ruby programming language allowing operators to send commands, verify telemetry, read and write files, access the network, and even send an email on completion. Advanced debugging functionality allows for single-stepping through procedures, setting breakpoints, and complete logging of all script and user interaction with the system. Detailed data visualization allows for custom screen creation, line and x-y plotting of data, and easy creation of custom 3d visualizations. Offline data analysis and data extraction capabilities make narrowing down anomalies easy. This presentation will discuss all the ways COSMOS can provide a superior, free, and open source command and control system to the small sat community.

INTRODUCTION

Ball Aerospace COSMOS empowers satellite developers of any size to easily create their own user interface for commanding and controlling a satellite or any other embedded system. COSMOS provides a fully featured test and operations system that provides commanding, automated test scripting, data visualization and much more. This paper discusses the huge amount of functionality available in Ball Aerospace COSMOS and its applicability specifically to small satellite developers.

TERMINOLOGY

The COSMOS system uses several terms that are important to understand. Many may be obvious to users within the aerospace industry, but the following table attempts to define these terms clearly for everyone.

Table 1: COSMOS Terminology

Term	Definition
Target	A COSMOS Target is an embedded system that COSMOS can send commands to and/or receive telemetry from.
Command	A packet of information telling a target to perform an action.
Telemetry Packet	A packet of information providing status from a target. Telemetry packets are either periodically received or may be received in response to a command.
Interface	A Ruby class that knows how to send commands to and/or receive telemetry from a target. COSMOS comes with interfaces that support TCP/IP, UDP, and serial connections. Custom interfaces are easy to add to the system.
Ruby	The powerful dynamic programming language used to write COSMOS applications and libraries. Also the language used in COSMOS scripts and test procedures.
Configuration Files	COSMOS uses simple plain text configuration files to define commands and telemetry packets, and to configure each COSMOS application. These files are easily

	human readable/editable and machine readable/editable.
Packet Log Files	Binary files containing either logged commands or telemetry packets.
Message Log Files	Text files containing messages generated by a tool.
Tool	Another name for a COSMOS application.

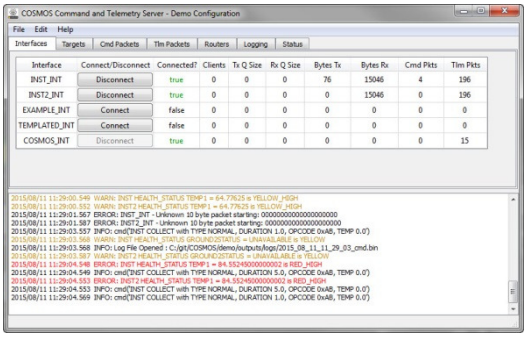
INCLUDED TOOLS

Ball Aerospace COSMOS comes with the following set of 15 applications that are directly available for use with minimal to no configuration.

Command and Telemetry Server

Command and Telemetry Server acts as the hub of the realtime portion of COSMOS. All commands and telemetry packets pass through this tool ensuring everything that happens is logged. It provides realtime commanding, telemetry reception, logging, limits monitoring, packet routing, and system status.

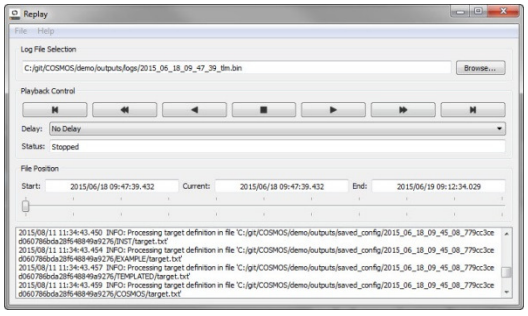
Figure 1: Command and Telemetry Server



Replay

Replay simulates the Command and Telemetry Server for telemetry packet log file playback. This enables use of any of the realtime tools with logged data. Replay is great for playing back scenarios and viewing them on telemetry screens.

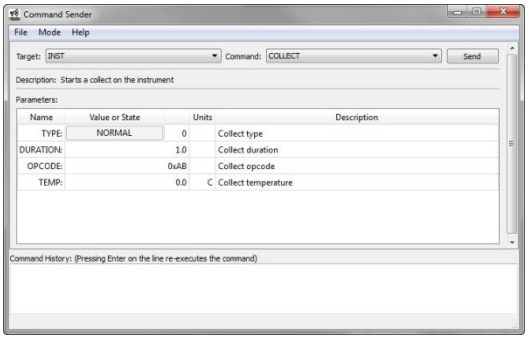
Figure 2: Replay



Command Sender

Command Sender provides a graphical interface for manually sending individual commands. Drop down selection of every command and command parameter in the system makes sending individual commands easy. A history pane makes resending previous commands easy.

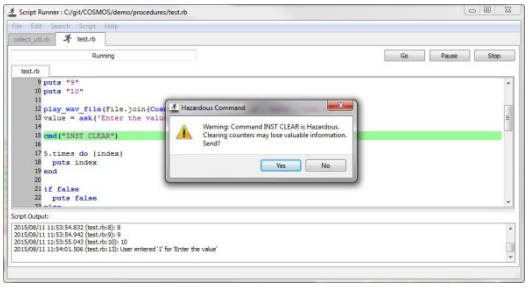
Figure 3: Command Sender



Script Runner

Script Runner executes test scripts and provides highlighting of the currently executing line. Scripts pause if any error occurs, breakpoints can be added, and lines can be reexecuted after a problem has been corrected.

Figure 4: Script Runner

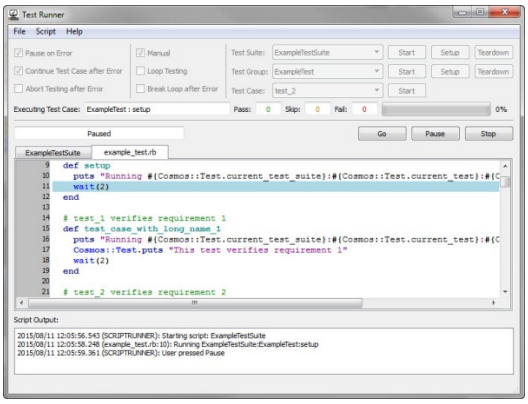


Test Runner

Test Runner provides a high level framework for system level testing including automatic test report generation. Test Runner brings the best features of software unit level testing to system level integration

and test by breaking tests down into easy understandable test cases. Users can execute entire test procedures or just the specific test cases they need to run for integration or regression tests.

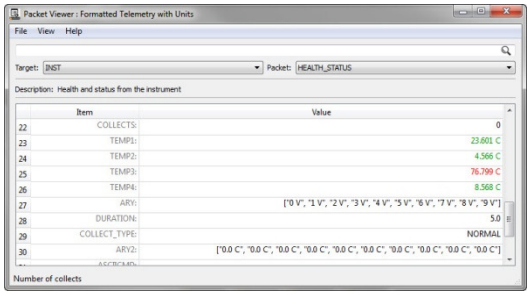
Figure 5: Test Runner



Packet Viewer

Packet Viewer provides realtime visualization of every telemetry packet that has been defined. Values within packets are displayed in a simple key-value format that requires no configuration. An autocomplete search bar makes finding values easy.

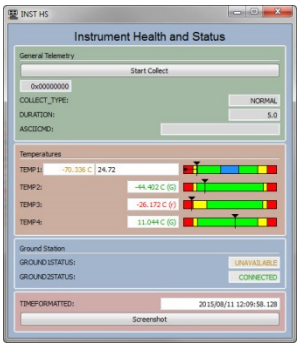
Figure 6: Packet Viewer



Telemetry Viewer

Telemetry Viewer provides custom telemetry screen functionality with advanced layout and visualization widgets. Tabs, graphs, limits bars, and other animated displays can be quickly created. Also, Telemetry Viewer can autogenerate a base set of screens for every telemetry packet that can be customized as needed.

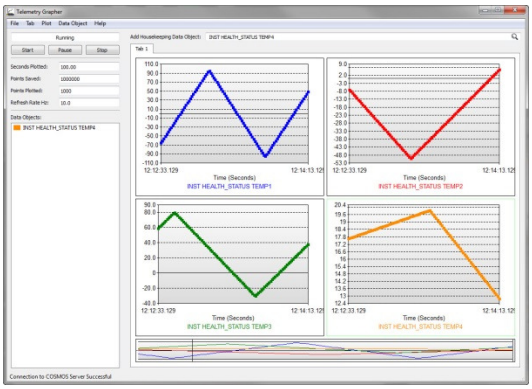
Figure 7: Telemetry Viewer



Telemetry Grapher

Telemetry Grapher provides realtime and offline graphing of telemetry data. Supports both line and x-y style plotting, with multiple tabs, plots, and items per plot. Includes built-in analysis functionality to graph min, max, difference, and standard deviation.

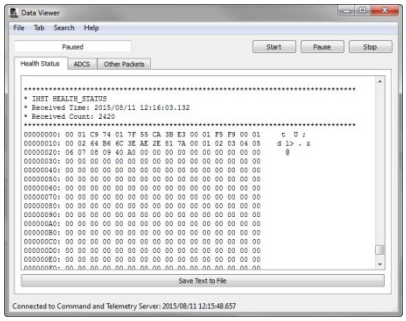
Figure 8: Telemetry Grapher



Data Viewer

Data Viewer provides text based telemetry visualization for items that don't fit into other data visualization paradigms. Great for scrolling log displays and memory dumps.

Figure 9: Data Viewer

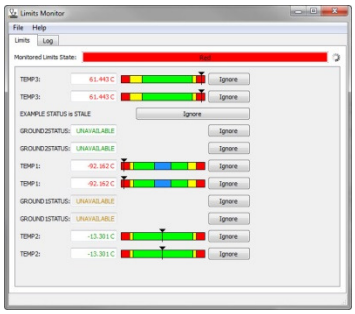


Limits Monitor

Limits Monitor monitors telemetry with defined limits and shows items that are currently out of limits or have

violated limits since the tool was started. Expected violations can be easily ignored.

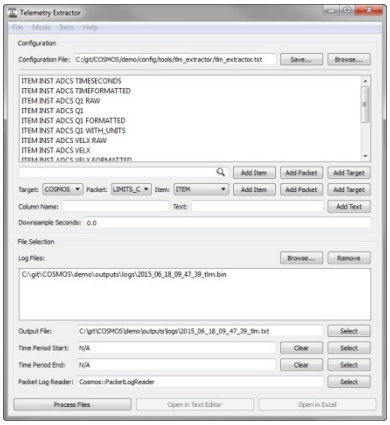
Figure 20: Limits Monitor



Telemetry Extractor

Telemetry Extractor extracts telemetry packet log files into CSV data. Highly configurable and supports batch processing to output multiple files at once.

Figure 11: Telemetry Extractor



Command Extractor

Command Extractor extracts command packet logs into human readable text.

Figure 12: Command Extractor

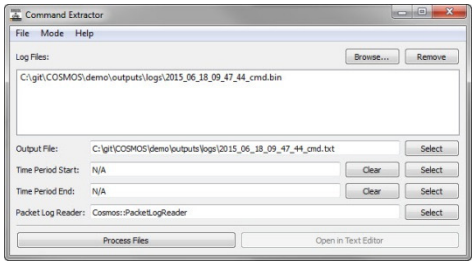
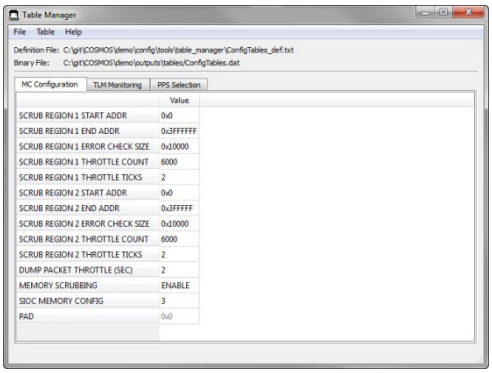


Table Manager

Table Manager is a binary file editor that can be used to create or edit configuration tables or other binary data.

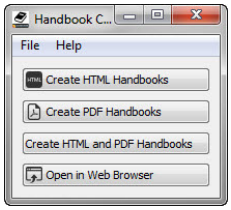
Figure 13: Table Manager



Handbook Creator

Handbook Creator creates html and pdf documentation of available commands and telemetry packets.

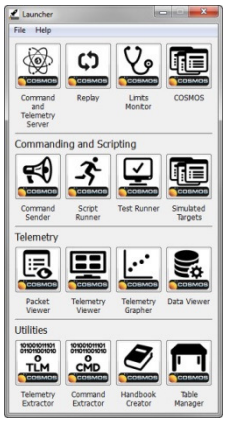
Figure 14: Handbook Creator



Launcher

Launcher provides a graphical user interface for launching each of the tools that make up the COSMOS system. Supports launching any application that can be started from the command line.

Figure 15: Launcher

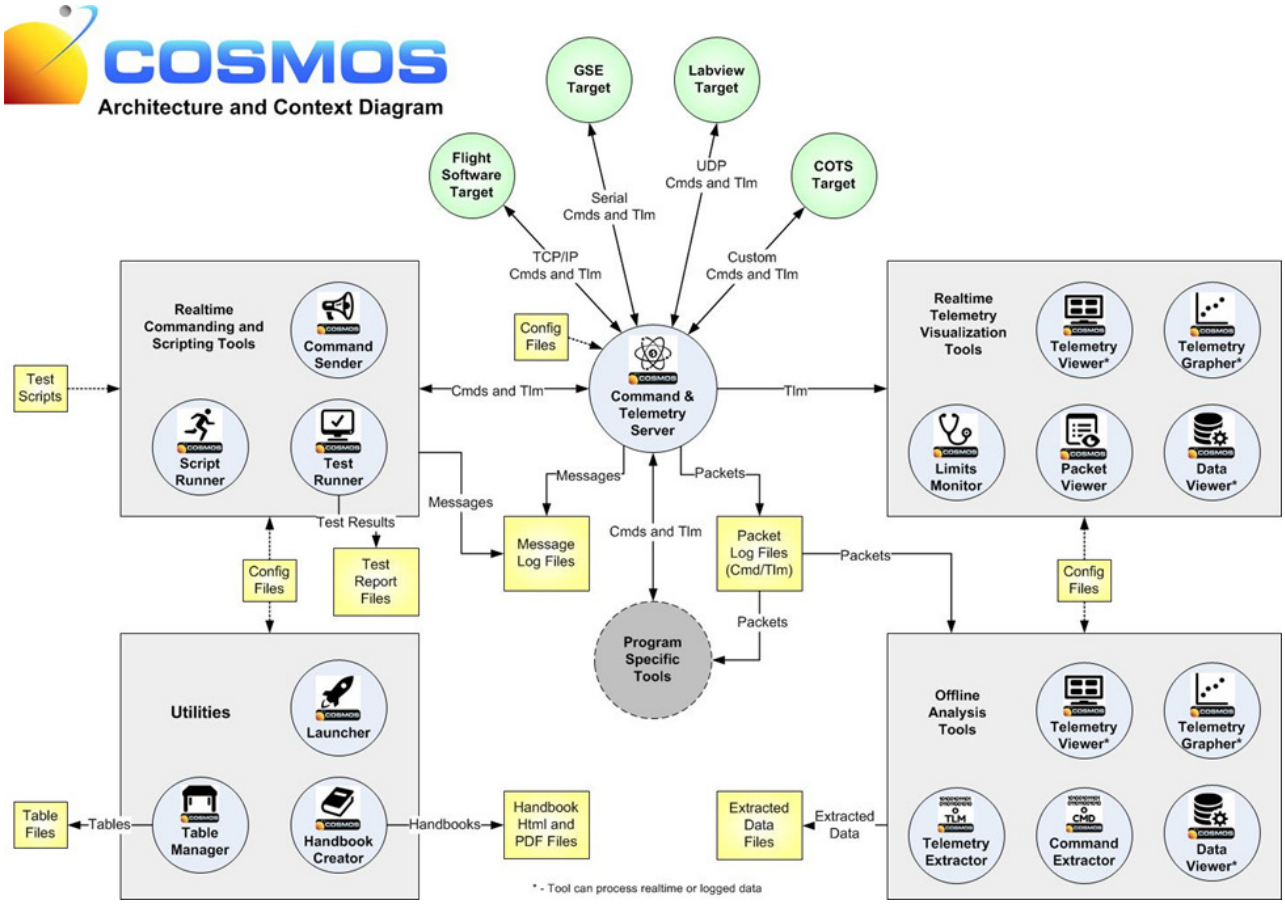


SYSTEM ARCHITECTURE

The Figure 16 shows how the 15 applications that make up the COSMOS system relate to each other and to the targets that COSMOS is controlling.

On the next page, the key aspects that make up the COSMOS System are discussed in detail.

Figure 16: COSMOS Architecture



Key Aspects

1. The COSMOS tools are grouped into four broad categories
    a. Realtime Command and Scripting
    b. Realtime Telemetry Visualization
    c. Offline Analysis
    d. Utilities
2. COSMOS can interface with many different kinds of targets. The examples shown in this diagram include Flight Software (FSW), Ground Support Equipment (GSE), Labview, and a Commercial Off-The-Shelf (COTS) target such as an Agilent Power Supply. Any embedded system that provides a communication interface can be connected to COSMOS.
3. COSMOS ships with interfaces for connecting over TCP/IP, UDP, and serial connections. COSMOS also supports custom interfaces to connect to anything that a computer can talk to.
4. All realtime communication with targets flows through the Command and Telemetry Server. This ensures all commands and telemetry are logged.
5. Every tool is configured with plain text configuration files (if any configuration is needed).
6. Project specific tools can be written using the COSMOS libraries that can interact with the realtime command and telemetry streams through the Command and Telemetry Server and can also do offline analysis of packet log files.
7. Cross Platform – COSMOS supports Windows, Linux, and Mac OSX.

KEY BENEFITS TO SMALL SATELLITES

Full Lifecycle System

Supports board level test, box level test, I&T, and on-orbit operations providing a consistent user interface throughout the full lifecycle of a product.

Logging

Everything is logged, and even more importantly, tools are provided to easily interpret and use the logs. Whenever an anomaly occurs there are tools already written that are ready to dig into the logs and help figure out what happened.

Superb Data Visualization

Anyone can create great telemetry displays, graph data in realtime, and provide an excellent sense of situational awareness – all without any programming required.

Powerful Scripting

COSMOS comes with a simple API that makes sending commands and checking telemetry easy. However, you are not constrained by your scripting language. COSMOS scripts are written in Ruby, a modern, fully functional scripting language. This allows you to read and write files, and perform live processing that most other systems force you to run offline.

Powerful Test Reporting and Organization

COSMOS Test Runner can produce very reliable test procedures that allow the user to easily execute the entire procedure or only a subset needed for a regression test. Automated test reports created at the end of every run make it very clear that everything passed successfully or where problems occurred.

HISTORY

COSMOS was first developed in 2006 and since then has been used to develop and test more than 30 flight programs at Ball including GMI, OLI, Kepler, WISE, OMPS, Ares, Orion, and numerous defense programs.

Since being open sourced in January 2015 it is now being used with at least 10 major corporations primarily for small satellite development and future operations.

SUMMARY

Ball Aerospace COSMOS is a free and open source command and control system that is immediately available for use. It provides a wealth of functionality much of which is not even available in expensive proprietary tools. For more information and to get started with Ball Aerospace COSMOS please see http://cosmosrb.com.

REFERENCES

1. Melton, Ryan, "Ball Aerospace COSMOS" *Retrieved from http://cosmosrb.com June 3rd, 2016*