openCMD

Interface Control Document

Subject: *The purpose of this document is to detail the operation and communication of the openCMD software package.*

Revision History

Revision 006

Revision	*Initials*	*Date*	*Comments*
001	Ljd	12/20/13	Initial.
002	Clr	09/20/14	Added content.
003	Meb	09/20/14	Edited content.
004	Clr	09/24/14	Added content.
005	Clr	06/04/15	Updated.
006	Meb	06/18/15	Proofread, edited content.

Table 1: Revision history.

Table of Contents

Revision History....2
1 Introduction....5
2 Purpose....5
3 More About openCMD....5
4 System States....6
4.1 State ID....6
4.1.1 Startup....6
4.1.2 Normal....6
4.1.3 Dormant....6
5 Motion Profiles....7
5.1 ECEF Decoupled 1....7
5.2 ECEF Decoupled 2....7
6 Database Signal Definitions....7
7 Communications....7
7.1 Type Definitions....8
7.2 Timing....8
7.3 PCOMMS Commands....8
8 Configuration....8
8.1 opencmd_app.yml....9
8.2 opencmd_lcm_config.yml....9

8.2.1 Available Subscription Keys....9
8.3 opencmd_scaling.yml....10
8.4 opencmd_signals.yml....10
8.5 opencmd_state_alarms.yml....10
8.6 opencmd_task_alarms.yml....10
9 Motion Configurations....10
9.1 Joystick....10
9.2 Bi-polar Controller Output....11
9.3 Controller Parameters....11
9.3.1 Gains....11
10 Tuning Systems....12
10.1 How to Tune openCMD....12
10.1.1 Effort....13
11 Appendix....14
11.1 Type Definitions....14
11.1.1 cmd_t....14
11.1.2 effort_t....15
11.1.3 ref_t....15
11.2 Database Signals....15
11.2.1 Status Signals....16
11.2.2 Command Signals....18
11.2.3 User Signals....21
11.3 Configuration Files....21
11.3.1 opencmd_app.yml....21
11.3.2 opencmd_lcm_config.yml....23
11.3.3 opencmd_state_alarms.yml....25
11.3.4 opencmd_motion_ecef_decoupled.yml....27

Index of Tables

Table 1: Revision history....2
Table 2: States and corresponding Ids....6
Table 3: Input type timeout intervals....8
Table 4: PCOMMS Commands....8
Table 5: openCMD configuration files and descriptions....9
Table 6: Subscription key names and descriptions....9

Table 7: Joystick keys and descriptions....10
Table 8: Bi-polar controller outputs and descriptions....11
Table 9: Controller parameters and descriptions....12
Table 10: Signals for six degrees of freedom....13
Table 11: cmd_t LCM type....14
Table 12: effort_t LCM type....15
Table 13: ref_t LCM type....15
Table 14: Status signal names and descriptions....18
Table 15: Command signal names and descriptions....21
Table 16: User signal names and descriptions....21

Illustration Index

Illustration 1: A flow chart of openCMD inputs/outputs....5
Illustration 2: openCMD's state task arbitration architecture....6
Illustration 3: Heading response in Data View....13

openCMD

Interface Control Document

1 Introduction

The openCMD package is part of the openSEA Suite and is based on the Open Software and Equipment Architecture (openSEA) proprietary to Greensea Systems, Inc. That makes it part of the foundation our Balefire control and navigation system is built upon.

openCMD provides the vehicle control with calculated control signals derived from the navigation solution provided. The application is designed to work seamlessly from the openINS navigation solution output, but can be configured with an existing navigation solution.

2 Purpose

This document dives into the openCMD software application. We'll discuss how its unique communications technology creates effective and accurate control. We'll also go through the different systems states, database signals, configurations, and everything else you need to know for running openCMD. You'll be a pro long before page 37. Don't worry.

This document is intended for general operators and assumes basic working knowledge of modern computer operating systems.

3 More About openCMD

As the control solution for the openSEA Suite software application package, openCMD provides users with a proven, flexible, and configurable six degree of freedom (SDOF) effort output to control vehicles in automated systems.

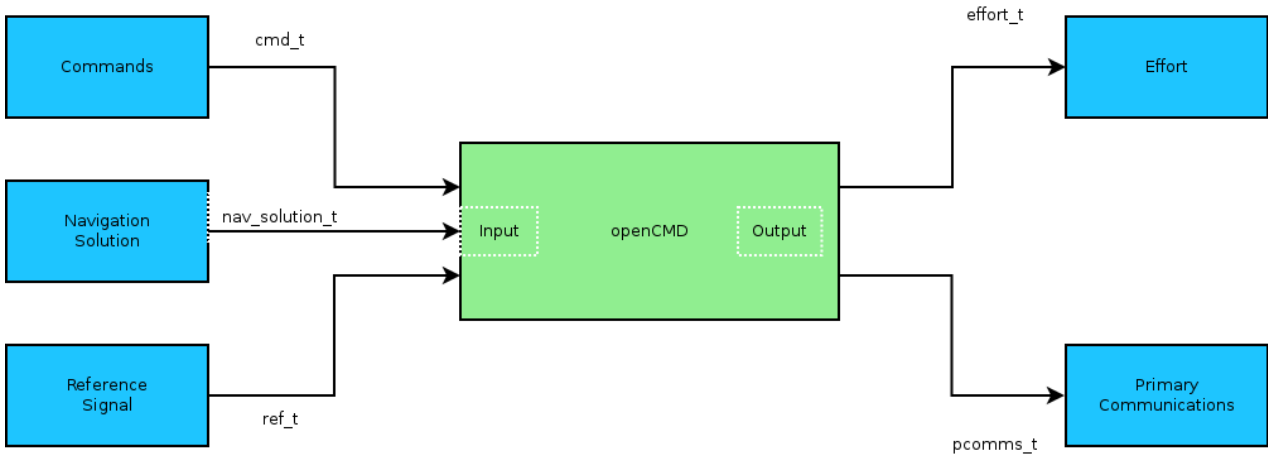

Illustration 1: A flow chart of openCMD inputs/outputs.

4 System States

openCMD uses openSEA's state task arbitration architecture. States determine the set of tasks currently being enabled, run, or disabled. Each state has context, an enable function, a run function, and a disable function. The context determines if the state is valid.

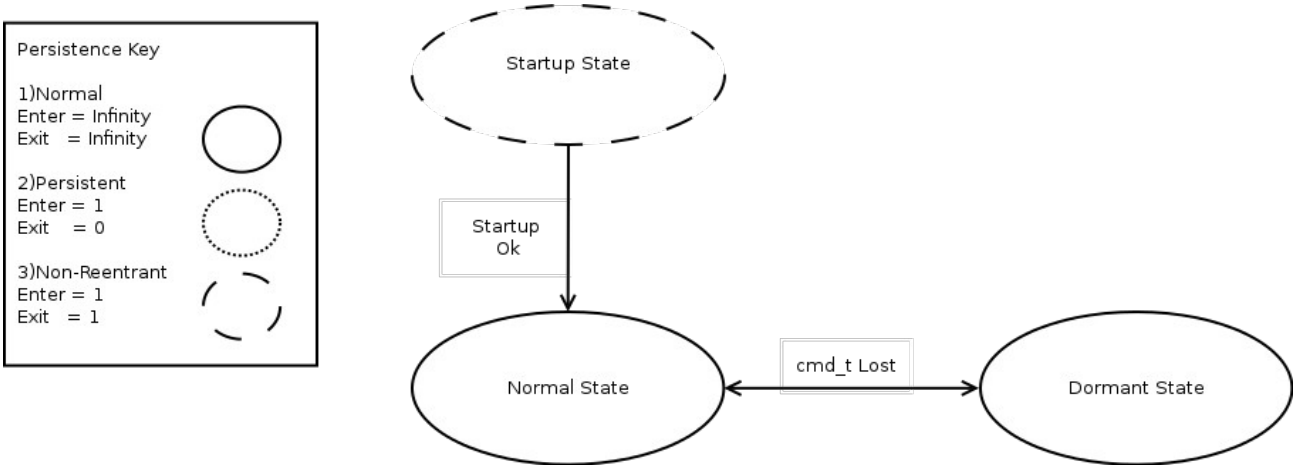

Illustration 2: openCMD's state task arbitration architecture.

4.1 State ID

Each state has an unique integer ID. The ID of the current state of the system is stored in the database under the S_STATE signal.

State	*State ID*
Startup	1
Normal	2
Dormant	3

Table 2: States and corresponding Ids

4.1.1 Startup

After the openCMD initialization the system enters Startup to ensure openCMD has properly initialized. This state is non-reentrant and will remain out of context for the remainder of the applications execution.

4.1.2 Normal

The Normal state is designed to be in context when all required elements of the openCMD application are working.

4.1.3 Dormant

openCMD will enter Dormant if there is a critical issue impeding normal operations. In other words, something is

wrong. The controllers will be set to secure mode and the output effort message will be set to the null when in Dormant.

5 Motion Profiles

Motion profiles determine how user command messages are interpreted and the type of controllers these commands will be pushed through. openCMD can only run one profile at a time. You can configure multiple profiles for a system and switch between these profiles as desired. Below is a table describing the currently available motion profiles.

Motion Profile	*Profile Identifier*
ECEF Decoupled 1	0x01
ECEF Decoupled 2	0x02

5.1 ECEF Decoupled 1

ECEF Decoupled provides six single DOF controllers in the world frame coordinate system. This allows users to provide latitude, longitude, depth, heading, pitch, and roll commanded set points directly to openCMD. Each of the SDOF controllers also provide reference input signals, allowing you to control the system based on an external reference. A typical use of the reference control mode is using the Z DOF reference mode for auto altitude following.

Both ECEF and reference control modes have control parameters allowing you to tune the controllers to your system. More on the available configurations parameters for ECEF Decoupled profile is provided in the configurations section.

5.2 ECEF Decoupled 2

ECEF Decoupled 2 provides the same controller setup as ECEF Decoupled 1, but gives the user a second set of control parameters for a system. The typical use for this second profile is when implementing a system with both remote and autonomous operational modes.

6 Database Signal Definitions

The openCMD database contains all of the signals used internally by openCMD. There are three types of data: status, command, and user input. Status signals always begin with S_. Command signals always begin with C_. User input signals always begin with U_. openCMD publishes the database as a pcomms_t LCM type at a down sampled rate. This information is used to communicate with other applications, tune the systems controllers, analyze the performance of the system, and data logging. See the appendix for references on the openCMD database.

7 Communications

All openSEA applications communicate using a publish/subscribe method aided by Lightweight Communications and Marshalling (LCM). This means openCMD data is organized into channels and transmitted as data types, which contain individual data signals. The types are published on a particular channel that openCMD must subscribe to in order to receive the data.

The openCMD application, which also subscribes to predefined channels, will publish data messages continuously on channels while running.

Input channels send data to the system and output channels send data out (see Illustration 1). Simple as that.

7.1 Type Definitions

Data types are a collection of data signals that can be transmitted on a channel for reception of another application. There are three types used in openCMD:

- cmd_t
- effort_t
- ref_t

The full list of signals for each type, as well as their descriptions, can be found in the appendix.

7.2 Timing

openCMD monitors the timing of the inputs it's subscribed too. Each input has a predetermined timeout value in which, if a message wasn't received within the timeout value, the data on the channel will be considered invalid. The following table describes the timeout intervals associated with the available input types:

Input Type	*Timeout [Seconds]*
cmd_t	0.25
nav_solution_t	0.25
ref_t	3

Table 3: Input type timeout intervals.

7.3 PCOMMS Commands

openCMD accepts PCOMMS commands for specific inputs into the system. Below is a table outlining the available PCOMMS commands:

PCOMMS Command Name	*Type*	*Description*
U_CHANNEL_NAV_SOLUTION	message_t	Set the subscription channel openCMD is listening for navigation solution messages.

Table 4: PCOMMS Commands

8 Configuration

To use an openCMD software package, the system must be configured properly. There are three types of configurations:

- Communication channels for other applications
- Fault tolerance / system error timeout settings
- Vehicle controller settings

The application details live in a config file inside the opencmd_config directory. The configuration file is a .yml file. A .yml, or YAML file stands for 'YAML Ain't Markup Language' format. The format is human readable configuration file,

providing you with the ability to tailor openCMD to your specific implementation.

Configuration File	*Description*
opencmd_app.yml	Main configuration file defining the set of configuration files to use.
opencmd_lcm_config.yml	Sets the subscribe channels used by openCMD.
opencmd_scaling.yml	Intended for future use.
opencmd_signals.yml	Intended for future use.
opencmd_state_alarms.yml	Defines the alarms used by the state arbiter.
opencmd_task_alarms.yml	Intended for future use.
opencmd_motion_auto_hdg2xy.yml	Motion controller parameters for auto_hdg2xy profile.
opencmd_motion_ecef_decoupled.yml	Motion controller parameters for ECEF decoupled profile.

Table 5: openCMD configuration files and descriptions.

8.1 opencmd_app.yml

This is the main configuration file for the application, providing openCMD with the set of configuration files needed for use. Each of these references is an individual .yml file containing data to set the defaults for the openCMD application. opencmd_app.yml is required as the first argument of the application. Scheduling defines the control threads that are used for device communication.

8.2 opencmd_lcm_config.yml

The LCM configuration file provides the subscription channels used for LCM communications. The file contains the channel name and device for commands, navigation, and references. This provides the details the command program needs to receive the required navigation data.

8.2.1 Available Subscription Keys

In order to register the channel you MUST use the the correct subscription key names. These are detailed in the following table:

Available Subscription Key Names	*Description*
cmd	Command
nav_solution	Navigation solution
ref	Reference signal
ctrl_config	Intended for future development
pcomms	Intended for future development

Table 6: Subscription key names and descriptions.

8.3 opencmd_scaling.yml

The scaling configuration file contains the default values used in scaling.

8.4 opencmd_signals.yml

The openCMD signals configuration file contains mapping details for the signals. The command system requires at least one signal be mapped properly for communication.

8.5 opencmd_state_alarms.yml

The state alarms configuration file contains the details to configure the sensitivity of the control system state alarm management. The alarms are:

- STARTUP_COMPLETE: The alarm to notify when the system has completed start up
- PCOMMS_LOST: The alarm to alert the operator when primary communications fail
- SYSTEM_OK: The alarm to return the status of the system when it is not operational

Look at the alarm configuration file; in the header there is a description of the types of configurations.

The details needed for each of these alarms are: name, enumerated value, alarm priority, threshold value to trigger alarm, delay value, alarm type and the message that will be sent when the alarm is triggered.

8.6 opencmd_task_alarms.yml

The state alarms configuration file contains the details to configure the necessary control system tasks. The details for each of these alarms are the same as those outlined under opencmd_state_alarms.yml.

9 Motion Configurations

The motion configuration files contain three main elements: joystick configurations, bi-polar controller output configurations, and controller parameters. We'll go over all three.

9.1 Joystick

The joystick parameters configure how the joystick effects the auto pilots. There are individual joystick configurations for each DOF as well as the reference DOF's.

Keys	*Description*
x_gain	Joystick Gain. Influences rate of change the joystick input has on controller effort command. Used for the FBW rate of command change. Negative value will switch direction of command change.
x_bias	Joystick Bias. Value will be added as a bias to joystick input.
x_db	Joystick Deadband. Deadband applied to joystick value after gain and bias application.

Table 7: Joystick keys and descriptions.

9.2 Bi-polar Controller Output

The bi-polar controller sets the parameters for the effort output. The range for controller output is -100 to 100 percent null at 0. This makes for generic output that's simple to map in whatever way you need to.

Invert switches the output direction, so if 100% was inverted it would be -100%. If the controller is diverging, say you command the vehicle to go left but it actually goes right, you'll want to invert the direction of the controller output. To do this, simply change the invert configuration to “true.”

The linear ramp filter limits how quickly a signal can change.

bp_cntrl	*Description*
id	Controller ID.
deadband	Controller Deadband.
invert	Invert the direction of the controller output.
range	Controller output range.
percent_of_range	Percent of range.
maximum	Maximum controller output value.
output_null	Controller null value.
minimum	Minimum controller output value.
maximum_rate_of_change	Maximum rate of change of the linear ramp filter.
linear_filter_enable	Ramp filter enable.

Table 8: Bi-polar controller outputs and descriptions.

9.3 Controller Parameters

9.3.1 Gains

Proportional gain ('P'): The proportional gain weights the proportional amount of error between the signal and the feedback, and maps it directly to the effort. The more error you have the more effort will be output.

Derivative Gain ('D'): The derivative gain weights the rate of error change over time.

Integral Gain ('I'): The integral gain weights the sum of error over time. This is important because a proportional error weighted at 5% or less may not seem like much, but it keeps growing over time. Letting the integral gain build up to a high number means you'll end up carrying around a large bias that could weigh the vehicle down.

Control	*Description*
K0	Proportional gain.
K1	Integral gain.
K2	Derivative gain.
K3	Output scalar
K4	Output bias gain.

K5	Reserved.
lim0	Integral lower limit.
lim1	Integral upper limit.
lim2	Command lower limit.
lim3	Command upper limit.
lim4	Control signal lower limit.
lim5	Control signal upper limit
enable_limit_0	Enable integral limit checking
enable_limit_1	Enable command limit checking.
enable_limit_2	Enable output limit checking.
enable_limit_3	Reserved.
enable_limit_4	Reserved.
enable_limit_5	Reserved.

Table 9: Controller parameters and descriptions.

10 Tuning Systems

Tuning is done to enable optimum autopilot performance and requires changing parameter values in the configurations file to suit your system. openCMD reads the configuration file on startup and sets the parameters for all controllers.

The dynamics of your particular vehicle dictate the values. Different vehicles have different masses, buoyancy, sensors, and thrusters, and those variables have a legitimate impact on gains.

If you have an accurate hydrodynamic model of your system you can analytically determine the controller gains for a plant. If you don't, you have to use other methods for tuning.

10.1 How to Tune openCMD

Steps for the tuning the control system:

1. Open the motion control configuration file you are tuning, either ECEF decoupled or hdg2xy, with a text editor. You'll have to know where the files are located. Usually, they're found in ~/gss_configs/opencmd_config.
2. Update the gains in the configuration file. Start tuning with proportional gain. Setting the ideal 'P' value takes trial and error. You want the output to overshoot the signal and oscillate about the setpoint. When you're happy with 'P', you should move on to derivative gain to iron out the oscillations. Then integral gain is changed if there's an offset between the set point and feedback signal.
3. Choose a controller to begin tuning and plot the relevant control signals using Balefire's Data View. The table below outlines the relevant control signals for the 6 DOF autopilots.

DOF	*Control Signal*	*Feedback Signal*
X	C_LON	S_SOLN_LON

DOF	*Control Signal*	*Feedback Signal*
Y	C_LAT	S_SOLN_LAT
Z	C_Z	S_SOLN_Z
Phi	C_PHI	S_SOLN_PHI
Theta	C_THETA	S_SOLN_THETA
Psi	C_PSI	S_SOLN_PS

Table 10: Signals for six degrees of freedom.

4. Place the vehicle into auto mode and check the response. One way to do this is by using the main Mission View page. You can try step responses when tuning, like for heading 15º steps at a time. It will also help to check dynamic control responses in addition to steps. To do this, turn on an autopilot like heading and drive forward or laterally. You'll want to check the chart in Data Plotter view to see how close or far the feedback is from the command signal. For heading you will look at the compass rose, for depth you'll look at the depth dial, and so on. Below is an example response of a heading controller plotted in Balefire's Data View.

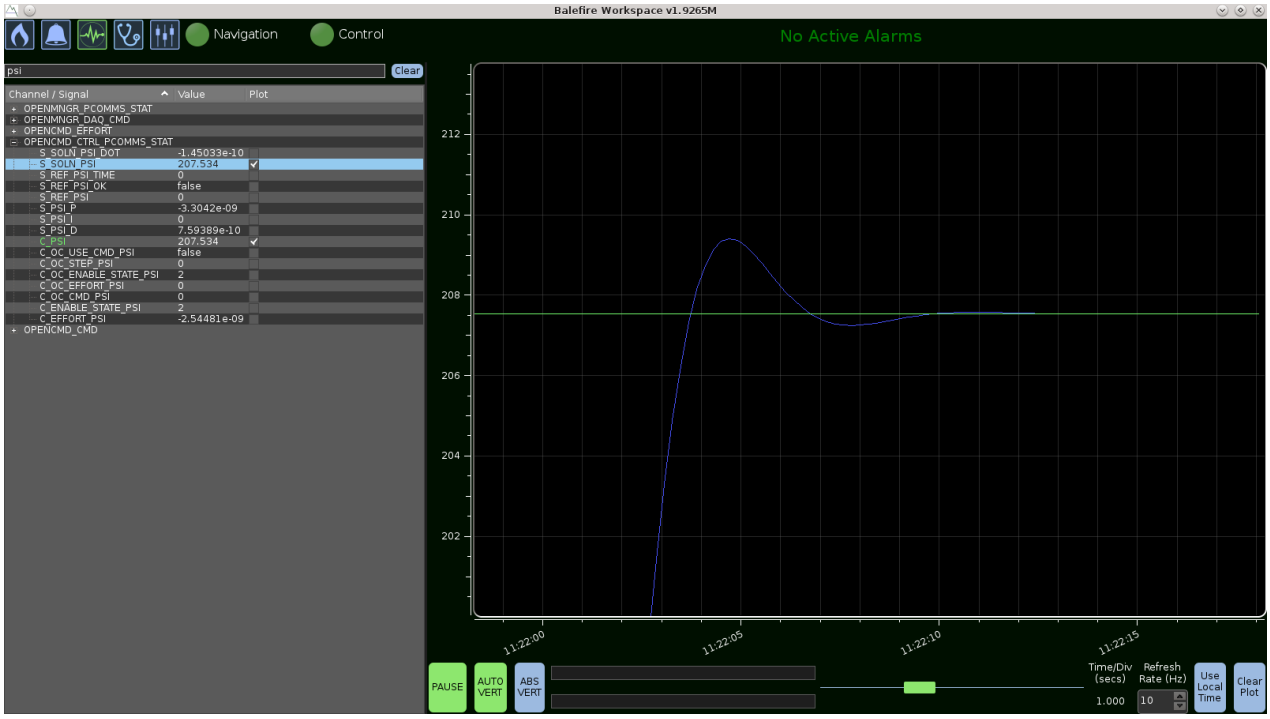

Illustration 3: Heading response in Data View.

5. Update and reload the the gains into openCMD by hitting the **Reconfigure Control** button. You can also send the user input signal U_RECONFIGURE_CTRL, marked “true,” in a pcomms message.

6. Repeat from 3 until satisfied with your control.

10.1.1 Effort

Checking the effort output and minimizing that effort is key to tuning. Initialize the openCMD effort

configuration file and track the change. If, for example, you see high frequency oscillations are not being damped you'll want to make changes to minimize the effort.

You do not want to go from 0 to 100 too quickly. Commanding 100% effort may result in accuracy, but it won't be robust.

11 Appendix

11.1 Type Definitions

11.1.1 cmd_t

cmd_t is the command type used by openCMD. This type sets for the current profiles, control signals, and enable states.

Variable	*Type*	*Description*
time_unix_sec	double	Unix Time stamps. The message data time stamp in seconds since January 1 1970, 12 p.m. GMT.
count_publish	int64_t	Incremented count value for the number of times the application published this message.
count_publish_error	int64_t	Error count value for the number of times an error was encountered during message transmissions. This includes “No communications” and device errors.
num_analogs	int32_t	Number of analog values.
analogs[num_analogs]	analog_t vector	Vector of analog values. The vector contains a name and a double value.
motion	int32_t	The motion profile selection identifier.
id_device	string	The device identification string. This ID is the manufacturer and model number for a hardware device.
enable_state_x enable_state_y enable_state_z enable_state_phi enable_state_theta enable_state_psi	int32_t	Each variable represents that specific enable state for that degree of freedom. This is an enumerated type unique to each profile. Specific definitions are provided in the openCMD documentation.
cmd_x cmd_y cmd_z cmd_phi cmd_theta cmd_psi	double	A command in units defined by the profile for each of the six degrees of freedom.

Table 11: cmd_t LCM type.

11.1.2 effort_t

effort_t transmits the control output efforts for the six degrees of freedom.

Variable	*Type*	*Description*
unix_time_sec	double	Unix Time stamps. The message data time stamp in seconds since January 1 1970, 12 p.m. GMT.
count_publish	int64_t	The increasing count of message data published.
count_publish_error	int64_t	The increasing count of errors that occurred during message transmission.
string_id_device	int32_t	The device identification string.
num_analogs	int32_t	The number of analog values.
analog[num_analogs]	analog_t	A vector of analog values.
effort_x effort_y effort_z effort_phi effort_theta effort_psi	double	The commanded effort in percentage for each degree of freedom.

Table 12: effort_t LCM type.

11.1.3 ref_t

The ref_t (reference type) is used to send reference signal inputs to openCMD for reference control.

Variable	*Type*	*Description*
unix_time_sec	double	Message data time stamp in seconds since Midnight, January 1, 1970 GMT.
count_publish	int64_t	The increasing count of message data published.
count_publish_error	int64_t	The increasing count of errors that occurred during message transmission.
num_analogs	int32_t	Number of analog signals.
id_device	string	ID of the device.
name	string	Name of the generic reference signal.
ref	double	Generic reference signal value.

Table 13: ref_t LCM type.

11.2 Database Signals

11.2.1 Status Signals

Database Signal Name	*Description*
S_STATE	Current state of the system.
S_SOLN_ALTITUDE	Solution for the altitude above the ground [meters].
S_SOLN_COG	Course over ground [degrees].
S_SOLN_COUNT_PUB	Number of navigation solution messages published.
S_SOLN_E	Relative Easting [meters].
S_SOLN_EACCEL	Easting acceleration [meters/seconds^2].
S_SOLN_EACCEL_BIAS	Easting acceleration bias [meters/seconds^2].
S_SOLN_E_DOT	Easting velocity [meters/seconds].
S_SOLN_INITFIX_LAT	Initial latitude fix [degrees].
S_SOLN_INITFIX_LON	Initial longitude fix [degrees].
S_SOLN_LAT	Current latitude [degrees].
S_SOLN_LON	Current longitude [degrees].
S_SOLN_N	Relative Northing [meters].
S_SOLN_NACCEL	Northing acceleration [meters/seconds^2].
S_SOLN_NACCEL_BIAS	Northing acceleration bias [meters/seconds^2].
S_SOLN_N_DOT	Northing velocity [meters/seconds].
S_SOLN_PHI	Phi (roll) [degrees].
S_SOLN_PHI_DOT	Phi (roll) velocity [degrees/seconds].
S_SOLN_PSI	Psi (heading) [degrees].
S_SOLN_PSI_DOT	Psi (heading) velocity [degrees/seconds].
S_SOLN_SOG	Speed over ground [meters/seconds].
S_SOLN_THETA	Theta (pitch) [degrees].
S_SOLN_THETA_DOT	Theta (pitch) velocity [degrees/seconds].
S_SOLN_TIME	Time the solution message was calculated [seconds].
S_SOLN_Z	Z axis solution (depth) [meters].
S_SOLN_ZACCEL	Z axis acceleration [meters/seconds^2].
S_SOLN_ZACCEL_BIAS	Z axis acceleration bias [meters/seconds^2].
S_SOLN_Z_DOT	Z axis velocity [meters/seconds].
S_X_P	Current X DOF proportional gain value.
S_X_I	Current X DOF integral gain value.
S_X_D	Current X DOF derivative gain value.
S_Y_P	Current Y DOF proportional gain value.
S_Y_I	Current Y DOF integral gain value.

Database Signal Name	*Description*
S_Y_D	Current Y DOF derivative gain value.
S_Z_P	Current Z DOF proportional gain value.
S_Z_I	Current Z DOF integral gain value.
S_Z_D	Current Z DOF derivative gain value.
S_PHI_P	Current phi DOF proportional gain value.
S_PHI_I	Current phi DOF integral gain value.
S_PHI_D	Current phi DOF derivative gain value.
S_THETA_P	Current theta DOF proportional gain value.
S_THETA_I	Current theta DOF integral gain value.
S_THETA_D	Current theta DOF derivative gain value.
S_PSI_P	Current psi DOF proportional gain value.
S_PSI_I	Current psi DOF integral gain value.
S_PSI_D	Current psi DOF derivative gain value.
S_REF_X	Current X reference signal.
S_REF_Y	Current Y reference signal.
S_REF_Z	Current Z reference signal.
S_REF_PHI	Current phi reference signal.
S_REF_THETA	Current theta reference signal.
S_REF_PSI	Current psi reference signal.
S_REF_X_TIME	Current X reference time [seconds].
S_REF_Y_TIME	Current Y reference time [seconds].
S_REF_Z_TIME	Current Z reference time [seconds].
S_REF_PHI_TIME	Current phi reference time [seconds].
S_REF_THETA_TIME	Current theta reference time [seconds].
S_REF_PSI_TIME	Current psi reference time [seconds].
S_REF_X_OK	Reference X signal OK [Boolean].
S_REF_Y_OK	Reference Y signal OK [Boolean].
S_REF_Z_OK	Reference Z signal OK [Boolean].
S_REF_PHI_OK	Reference phi signal OK [Boolean].
S_REF_THETA_OK	Reference theta signal OK [Boolean].
S_REF_PSI_OK	Reference psi signal OK [Boolean].
S_SOLN_ALT_OK	Altitude OK [Boolean].
S_SOLN_ATTITUDE_OK	Attitude OK [Boolean].
S_SOLN_BTMLOCK	Bottom Lock OK [Boolean].

Database Signal Name	*Description*
S_SOLN_DEPTH_OK	Depth OK [Boolean].
S_SOLN_LATLONPOS_OK	Latitude and longitude OK [Boolean].
S_SOLN_RELPOS_OK	Relative positioning OK [Boolean].
S_SOLN_ABSPOS_OK	Absolute positioning OK [Boolean].
S_SOLN_SPEED_OK	Speed OK [Boolean].
S_DATA_MADE_OK	Database created successfully OK [Boolean].
S_SIGNALS_MADE_OK	Signals created successfully OK [Boolean].
S_DEVICES_MADE_OK	Devices created successfully OK [Boolean].
S_PCOMMS_MADE_OK	Primary communications create successfully OK [Boolean].
S_STATES_MADE_OK	State created successfully OK [Boolean].
S_TASKS_MADE_OK	Tasks create successfully OK [Boolean].
S_THREADS_MADE_OK	Threads created successfully OK [Boolean].
S_SYSTEM_READY_OK	System ready and OK [Boolean].
S_STARTUP_COMPLETE	Startup complete [Boolean].
S_SYSTEM_OK	System OK [Boolean].
S_SS_PCOMMS_OK	Primary communications OK [Boolean].
S_SS_PCOMMS_DT	Delta time between last primary communications reception [seconds].
S_SS_PCOMMS_LAST_RX	Time of last primary communications reception [seconds].

Table 14: Status signal names and descriptions.

11.2.2 Command Signals

Database Signal Name	*Description*
C_CTRL_CONFIG_TIME	Intended for future use.
C_CTRL_CONFIG_PROFILE	Intended for future use.
C_CTRL_CONFIG_DOF	Intended for future use.
C_CTRL_CONFIG_TRACKING	Intended for future use.
C_CTRL_CONFIG_KO	Intended for future use.
C_CTRL_CONFIG_K1	Intended for future use.
C_CTRL_CONFIG_K2	Intended for future use.
C_CTRL_CONFIG_K3	Intended for future use.
C_CTRL_CONFIG_K4	Intended for future use.
C_CTRL_CONFIG_K5	Intended for future use.

Database Signal Name	*Description*
C_CTRL_CONFIG_LIMIT0	Intended for future use.
C_CTRL_CONFIG_LIMIT1	Intended for future use.
C_CTRL_CONFIG_LIMIT2	Intended for future use.
C_CTRL_CONFIG_LIMIT3	Intended for future use.
C_CTRL_CONFIG_LIMIT4	Intended for future use.
C_CTRL_CONFIG_LIMIT5	Intended for future use.
C_CTRL_CONFIG_ENABLE_LIMIT0	Intended for future use.
C_CTRL_CONFIG_ENABLE_LIMIT1	Intended for future use.
C_CTRL_CONFIG_ENABLE_LIMIT2	Intended for future use.
C_CTRL_CONFIG_ENABLE_LIMIT3	Intended for future use.
C_CTRL_CONFIG_ENABLE_LIMIT4	Intended for future use.
C_CTRL_CONFIG_ENABLE_LIMIT5	Intended for future use.
C_CTRL_CONFIG_BPCTRL_MAX_RANGE	Intended for future use.
C_CTRL_CONFIG_BPCTRL_MIN_RANGE	Intended for future use.
C_OC_TIME	Current cmd_t message time [seconds].
C_OC_PROFILE	Current cmd_t message profile.
C_OC_EFFORT_X	Current cmd_t message X effort.
C_OC_EFFORT_Y	Current cmd_t message Y effort.
C_OC_EFFORT_Z	Current cmd_t message Z effort.
C_OC_EFFORT_PHI	Current cmd_t message phi effort.
C_OC_EFFORT_THETA	Current cmd_t message theta effort.
C_OC_EFFORT_PSI	Current cmd_t message psi effort.
C_OC_STEP_X	Current cmd_t message X step.
C_OC_STEP_Y	Current cmd_t message Y step.
C_OC_STEP_Z	Current cmd_t message Z step.
C_OC_STEP_PHI	Current cmd_t message phi step.
C_OC_STEP_THETA	Current cmd_t message theta step.
C_OC_STEP_PSI	Current cmd_t message psi step.
C_OC_CMD_X	Current cmd_t message commanded X.
C_OC_CMD_Y	Current cmd_t message commanded Y.
C_OC_CMD_Z	Current cmd_t message commanded Z.
C_OC_CMD_PHI	Current cmd_t message commanded phi.
C_OC_CMD_THETA	Current cmd_t message commanded theta.
C_OC_CMD_PSI	Current cmd_t message commanded psi.

Database Signal Name	*Description*
C_OC_ENABLE_STATE_X	Current cmd_t message X enable state.
C_OC_ENABLE_STATE_Y	Current cmd_t message Y enable state
C_OC_ENABLE_STATE_Z	Current cmd_t message Z enable state
C_OC_ENABLE_STATE_PHI	Current cmd_t message phi enable state
C_OC_ENABLE_STATE_THETA	Current cmd_t message theta enable state
C_OC_ENABLE_STATE_PSI	Current cmd_t message psi enable state
C_PROFILE	Currently active profile.
C_LAT	Commanded latitude [degrees].
C_LONG	Commanded longitude [degrees].
C_X	Commanded X [meters].
C_Y	Commanded Y[meters].
C_Z	Commanded Z [meters].
C_PHI	Commanded phi [degrees].
C_THETA	Commanded theta [degrees].
C_PSI	Commanded psi [degrees].
C_ENABLE_STATE_X	Current X enable state.
C_ENABLE_STATE_Y	Current Y enable state.
C_ENABLE_STATE_Z	Current Z enable state.
C_ENABLE_STATE_PHI	Current phi enable state.
C_ENABLE_STATE_THETA	Current theta enable state.
C_ENABLE_STATE_PSI	Current psi enable state.
C_EFFORT_X	Current X effort [percent].
C_EFFORT_Y	Current Y effort [percent].
C_EFFORT_Z	Current Z effort [percent].
C_EFFORT_PHI	Current phi effort [percent].
C_EFFORT_THETA	Current theta effort [percent].
C_EFFORT_PSI	Current psi effort [percent].
C_OC_USE_CMD_X	Signal to use the currently commanded X [Boolean].
C_OC_USE_CMD_Y	Signal to use the currently commanded Y [Boolean].
C_OC_USE_CMD_Z	Signal to use the currently commanded Z [Boolean].
C_OC_USE_CMD_PHI	Signal to use the currently commanded phi [Boolean].
C_OC_USE_CMD_THETA	Signal to use the currently commanded theta [Boolean].
C_OC_USE_CMD_PSI	Signal to use the currently commanded psi [Boolean].
C_CTRL_CONFIG_UPDATE_KO	Intended for future use.

Database Signal Name	*Description*
C_CTRL_CONFIG_UPDATE_K1	Intended for future use.
C_CTRL_CONFIG_UPDATE_K2	Intended for future use.
C_CTRL_CONFIG_UPDATE_K3	Intended for future use.
C_CTRL_CONFIG_UPDATE_K4	Intended for future use.
C_CTRL_CONFIG_UPDATE_K5	Intended for future use.
C_CTRL_CONFIG_UPDATE_LIMIT0	Intended for future use.
C_CTRL_CONFIG_UPDATE_LIMIT1	Intended for future use.
C_CTRL_CONFIG_UPDATE_LIMIT2	Intended for future use.
C_CTRL_CONFIG_UPDATE_LIMIT3	Intended for future use.
C_CTRL_CONFIG_UPDATE_LIMIT4	Intended for future use.
C_CTRL_CONFIG_UPDATE_LIMIT5	Intended for future use.
C_CTRL_CONFIG_UPDATE_ENABLE_LIMIT0	Intended for future use.
C_CTRL_CONFIG_UPDATE_ENABLE_LIMIT1	Intended for future use.
C_CTRL_CONFIG_UPDATE_ENABLE_LIMIT2	Intended for future use.
C_CTRL_CONFIG_UPDATE_ENABLE_LIMIT3	Intended for future use.
C_CTRL_CONFIG_UPDATE_ENABLE_LIMIT4	Intended for future use.
C_CTRL_CONFIG_UPDATE_ENABLE_LIMIT5	Intended for future use.
C_CTRL_CONFIG_UPDATE_BPCTRL_MAX_RANGE	Intended for future use.
C_CTRL_CONFIG_UPDATE_BPCTRL_MIN_RANGE	Intended for future use.

Table 15: Command signal names and descriptions.

11.2.3 User Signals

Database Signal Name	*Description*
U_RECONFIGURE_CTRL	Reload the control configuration parameters.

Table 16: User signal names and descriptions.

11.3 Configuration Files

11.3.1 opencmd_app.yml

```
##############################################################################
#
# openCMD
#
```

```
# General Application configuration file
#
# error_logging_level
#   0 = Debug
#   1 = Info
#   2 = Warning
#   3 = Severe
#   4 = Fatal
#
# Greensea Systems, Inc.
# 10 East Main Street
# Richmond, Vermont  05465
# 802.434.6080
# www.greenseainc.com
################################################################################

motion_controller_ecef_decoupled:
  file: opencmd_config/opencmd_motion_ecef_decoupled.yml
  error_logging_level: 0

motion_controller_auv_hdg2xy:
  file: opencmd_config/opencmd_motion_auto_hdg2xy.yml
  error_logging_level: 0

application_configuration:

  data:
    scaling_config:      opencmd_config/opencmd_scaling.yml
    error_logging_level: 1

  signals:
    signal_config:       opencmd_config/opencmd_signals.yml
    error_logging_level: 0
```

```
arbiter:
  state_alarms: opencmd_config/opencmd_state_alarms.yml
  error_logging_level: 1

tasker:
  task_alarms: opencmd_config/opencmd_task_alarms.yml
  error_logging_level: 0

transforms:
  xform_config: opencmd_config/opencmd_xforms.yml

lcm_devices:
  lcm_config: opencmd_config/opencmd_lcm_config.yml

scheduling:
  acontrol: 50  # arby, tasker,conn_diag, wypt,pcomms, alrms,validate
  qcontrol: 150 # NOOP
  pcontrol: 250 # Handle This will never sleep
  scontrol: 350 # NOOP
```

11.3.2 opencmd_lcm_config.yml

```
##############################################################################
#
# LCM Device Configuration File
#
# Provides the Subscribe Channel for a Selected Device
#
#parameter:
#  channel: YOUR_CHANNEL
#  device: your_device
#
#
```

```
# Greensea Systems, Inc.
# 10 East Main Street
# Richmond, Vermont  05465
# 802.434.6080
# www.greenseainc.com
################################################################################

#Nav Solution
nav_solution:
  channel: OPENINS_NAV_SOLUTION
  device: nav

#Command
cmd:
  channel: OPENCMD_CMD
  device: cmd

#Reference
ref:
  channel: OPENCMD_REF
  device: ref

# Controller Configuration Message
ctrl_config:
  channel: OPENCMD_CTRL_CONFIG
  device: ctrl_config

#Pcomms
pcomms:
  channel: OPENCMD_PCOMMS_CMD
  device: pcomms

#END
```

11.3.3 opencmd_state_alarms.yml

```
##############################################################################
#
# openCMD state alarms
#
# Alarms configuration file
# Each entry has the following format
# - name:               alarm name without spaces
#   bind_to_element:    the greensea signal to which this alarm is bound
#   priority:           the priority level of the alarm
#   threshold_value:
#   delay_value:
#   type:
#   message:            what you want to appear in the alarm window
#
# Do not modify this file unless you know what you are doing.
#
#  Alarm Priority Levels
#  0 = INFO
#  1 = WARNING
#  2 = SEVERE
#
#  Alarm types
#  0 = BOOLEAN
#  1 = MINIMUM THRESHOLD
#  2 = MAXIMUM THRESHOLD
#  3 = EQUAL THRESHOLD
#
# Greensea Systems, Inc.
# 10 East Main Street
# Richmond, Vermont  05465
# 802.434.6080
# www.greenseainc.com
```

```
################################################################################

# | <=== *Everything* must line up with this line = TWO SPACES
alarms:
- name: STARTUP_COMPLETE
  bind_to_element: S_STARTUP_COMPLETE
  priority: 0
  threshold_value: 1
  delay_value: 0.0
  type: 0
  message: STARTUP Complete

- name: PCOMMS_LOST
  bind_to_element: S_SS_PCOMMS_DT
  priority: 2
  threshold_value: 2.0
  delay_value: 0.0
  type: 2
  message: PCOMMS Lost

- name: SYSTEM_OK
  bind_to_element: S_SYSTEM_OK
  priority: 2
  threshold_value: 0
  delay_value: 0.0
  type: 0
  message: System Failure
```

11.3.4 opencmd_motion_ecef_decoupled.yml

```
##############################################################################
#
# openCMD
#
# Motion control configuration file
#
# Greensea Systems, Inc.
# 10 East Main Street
# Richmond, Vermont  05465
# 802.434.6080
# www.greenseainc.com
##############################################################################

# | <=== *Everything* must line up with this line = TWO SPACES
joystick:
  x_gain: 1.0
  x_bias: 0.0
  x_db: 0.0
  y_gain: 1.0
  y_bias: 0.0
  y_db: 0.0
  z_gain: -0.008
  z_bias: 0.0
  z_db: 0.0
  phi_gain: 1.0
  phi_bias: 0.0
  phi_db: 0.0
  theta_gain: 1.0
  theta_bias: 0.0
  theta_db: 0.0
  psi_gain: 0.04
```

psi_bias: 0.0

psi_db: 0.0

xref_gain: 1.0

xref_bias: 0.0

xref_db: 0.0

yref_gain: 1.0

yref_bias: 0.0

yref_db: 0.0

zref_gain: 0.008

zref_bias: 0.0

zref_db: 0.0

phiref_gain: 1.0

phiref_bias: 0.0

phiref_db: 0.0

thetaref_gain: 1.0

thetaref_bias: 0.0

thetaref_db: 0.0

psiref_gain: 1.0

psiref_bias: 0.0

psiref_db: 0.0

x_bpcontrol:

id: 0

deadband: 0

invert: false

range: 100

percent_of_range: 100

maximum: 100

output_null: 0

minimum: -100

maximum_rate_of_change: 100

linear_filter_enable: false

```
x_control:
  k0: 30.0
  k1: 0.0
  k2: 10.5
  k3: -1.0
  k4: 0.0
  k5: 0.0
  lim0: -100.0
  lim1: 100.0
  lim2: 0.0
  lim3: 100.0
  lim4: -70.0
  lim5: 70.0
  enable_limit_0: TRUE
  enable_limit_1: TRUE
  enable_limit_2: TRUE
  enable_limit_3: TRUE
  enable_limit_4: TRUE
  enable_limit_5: TRUE

xref_control:
  k0: 30.0
  k1: 1.0
  k2: 10.5
  k3: 1.0
  k4: 0.0
  k5: 0.0
  lim0: -100.0
  lim1: 100.0
  lim2: 0.0
  lim3: 100.0
  lim4: -50.0
  lim5: 50.0
```

```
  enable_limit_0: TRUE
  enable_limit_1: TRUE
  enable_limit_2: TRUE
  enable_limit_3: TRUE
  enable_limit_4: TRUE
  enable_limit_5: TRUE

y_bpcontrol:
  deadband: 0
  invert: false
  range: 100
  percent_of_range: 100
  maximum: 100
  output_null: 0
  minimum: -100
  maximum_rate_of_change: 100
  linear_filter_enable: false

y_control:
  k0: 30.0
  k1: 0.0
  k2: 10.5
  k3: -1.0
  k4: 0.0
  k5: 0.0
  lim0: -100.0
  lim1: 100.0
  lim2: 0.0
  lim3: 100.0
  lim4: -70.0
  lim5: 70.0
  enable_limit_0: TRUE
  enable_limit_1: TRUE
```

```
  enable_limit_2: TRUE
  enable_limit_3: TRUE
  enable_limit_4: TRUE
  enable_limit_5: TRUE

yref_control:
  k0: 20.0
  k1: 1.0
  k2: 10.5
  k3: -1.0
  k4: 0.0
  k5: 0.0
  lim0: -100.0
  lim1: 100.0
  lim2: 0.0
  lim3: 100.0
  lim4: -50.0
  lim5: 50.0
  enable_limit_0: TRUE
  enable_limit_1: TRUE
  enable_limit_2: TRUE
  enable_limit_3: TRUE
  enable_limit_4: TRUE
  enable_limit_5: TRUE

z_bpcontrol:
  deadband: 0
  invert: false
  range: 100
  percent_of_range: 100
  maximum: 100
  output_null: 0
  minimum: -100
```

```
  maximum_rate_of_change: 100
  linear_filter_enable: false

z_control:
  k0: 20.0
  k1: 0.0
  k2: 0.0
  k3: -1.0
  k4: 0.0
  k5: 0.0
  lim0: -20.0
  lim1: 20.0
  lim2: 0.0
  lim3: 100.0
  lim4: -70
  lim5: 70
  enable_limit_0: FALSE
  enable_limit_1: FALSE
  enable_limit_2: TRUE
  enable_limit_3: TRUE
  enable_limit_4: TRUE
  enable_limit_5: TRUE

zref_control:
  k0: 20.0
  k1: 0.0
  k2: 0.0
  k3: 1.0
  k4: 0.0
  k5: 0.0
  lim0: -20.0
  lim1: 20.0
  lim2: 0.0
```

```
  lim3: 100.0
  lim4: -60
  lim5: 60
  enable_limit_0: FALSE
  enable_limit_1: FALSE
  enable_limit_2: TRUE
  enable_limit_3: TRUE
  enable_limit_4: TRUE
  enable_limit_5: TRUE

phi_bpcontrol:
  deadband: 0
  invert: false
  range: 100
  percent_of_range: 100
  maximum: 100
  output_null: 0
  minimum: -100
  maximum_rate_of_change: 100
  linear_filter_enable: false

phi_control:
  k0: 30.3
  k1: 0.0
  k2: 0.0
  k3: 1.0
  k4: 0.0
  k5: 0.0
  lim0: -0.3
  lim1: 0.3
  lim2: -6.283009
  lim3: 6.283009
  lim4: -20.0
```

lim5: 20.0
enable_limit_0: TRUE
enable_limit_1: TRUE
enable_limit_2: TRUE
enable_limit_3: TRUE
enable_limit_4: TRUE
enable_limit_5: TRUE

phiref_control:
k0: 30.3
k1: 0.0
k2: 0.0
k3: 1.0
k4: 0.0
k5: 0.0
lim0: -0.3
lim1: 0.3
lim2: -6.283009
lim3: 6.283009
lim4: -20.0
lim5: 20.0
enable_limit_0: TRUE
enable_limit_1: TRUE
enable_limit_2: TRUE
enable_limit_3: TRUE
enable_limit_4: TRUE
enable_limit_5: TRUE

theta_bpcontrol:
deadband: 0
invert: false
range: 100
percent_of_range: 100

```
  maximum: 100
  output_null: 0
  minimum: -100
  maximum_rate_of_change: 100
  linear_filter_enable: false

theta_control:
  k0: 30.4
  k1: 0.0
  k2: 0.0
  k3: 1.0
  k4: 0.0
  k5: 0.0
  lim0: -0.3
  lim1: 0.3
  lim2: -6.283009
  lim3: 6.283009
  lim4: -20.0
  lim5: 20.0
  enable_limit_0: TRUE
  enable_limit_1: TRUE
  enable_limit_2: TRUE
  enable_limit_3: TRUE
  enable_limit_4: TRUE
  enable_limit_5: TRUE

thetaref_control:
  k0: 30.5
  k1: 0.0
  k2: 0.0
  k3: 1.0
  k4: 0.0
  k5: 0.0
```

lim0: -0.3
lim1: 0.3
lim2: -6.283009
lim3: 6.283009
lim4: -20.0
lim5: 20.0
enable_limit_0: TRUE
enable_limit_1: TRUE
enable_limit_2: TRUE
enable_limit_3: TRUE
enable_limit_4: TRUE
enable_limit_5: TRUE

psi_bpcontrol:
deadband: 0
invert: false
range: 100
percent_of_range: 100
maximum: 100
output_null: 0
minimum: -100
maximum_rate_of_change: 100
linear_filter_enable: false

psi_control:
k0: 440.0
k1: 0.0
k2: 300.0
k3: 1.0
k4: 0.0
k5: 0.0
lim0: -0.3
lim1: 0.3

lim2: -6.283009
lim3: 6.283009
lim4: -30.0
lim5: 30.0
enable_limit_0: TRUE
enable_limit_1: TRUE
enable_limit_2: TRUE
enable_limit_3: TRUE
enable_limit_4: TRUE
enable_limit_5: TRUE

psiref_control:
k0: 60.3
k1: 0.5
k2: 30.0
k3: 1.0
k4: 0.0
k5: 0.0
lim0: -0.3
lim1: 0.3
lim2: -6.283009
lim3: 6.283009
lim4: -20.0
lim5: 20.0
enable_limit_0: TRUE
enable_limit_1: TRUE
enable_limit_2: TRUE
enable_limit_3: TRUE
enable_limit_4: TRUE
enable_limit_5: TRUE

End Page