Mach and CyFlex®

May 22, 2023

Developed by SGS North America, Inc.

Document Conventions

This document uses the following typographic and syntax conventions.

- Commands, command options, file names or any user-entered input appear in Courier type. Variables appear in Courier italic type.

  Example: Select the `cmdapp-relVersion-buildVersion.zip` file....

- User interface elements, such as field names, button names, menus, menu commands, and items in clickable dropdown lists, appear in Arial bold type.

  Example: **Type**: Click **Select Type** to display drop-down menu options.

- Cross-references are designated in Arial italics.
  Example: Refer to *Figure 1*…
- Click intra-document cross-references and page references to display the stated destination.
  Example: Refer to *Section 1 Mach and* CyFlex Introduction on page 1.
    The clickable cross-references in the preceding example are *1*, *Installation Procedure*, and on page 1.

CyFlex Documentation

CyFlex manuals are available at https://cyflex.com/. View **Help & Docs** topics or use the **Search** facility to find topics of interest.

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1 Mach and CyFlex Introduction

Most Cummins engineering users know that they can retrieve their test cell data from DARTS and their retrieval can include many calculated results. Not all users know that DARTS uses Mach in the background to perform these calculations. Calculation capabilities of Mach are available for CyFlex in several ways.

Four aspects comprise Mach and CyFlex:

1. Mach calculations can be performed as tests are being run. See *Section 2 Mach on CyFlex* on page 3 for details.
2. Mach calculation files can be investigated using `mach_diagnose`. See *Section 1.3 Mach Diagnostics* on page 2 for details.
3. Setting up CyFlex for Mach calculations can be done using Mach setup assistance. See *Section 3 Mach Setup Assistance* on page 5 for details.
4. Final checks of Mach calculations can be done using Mach data checking. See *Section 4 Mach Data Checking* on page 8 for details.

Figure 1 illustrates the Mach and CyFlex architecture.

Figure 1: Mach and CyFlex Architecture
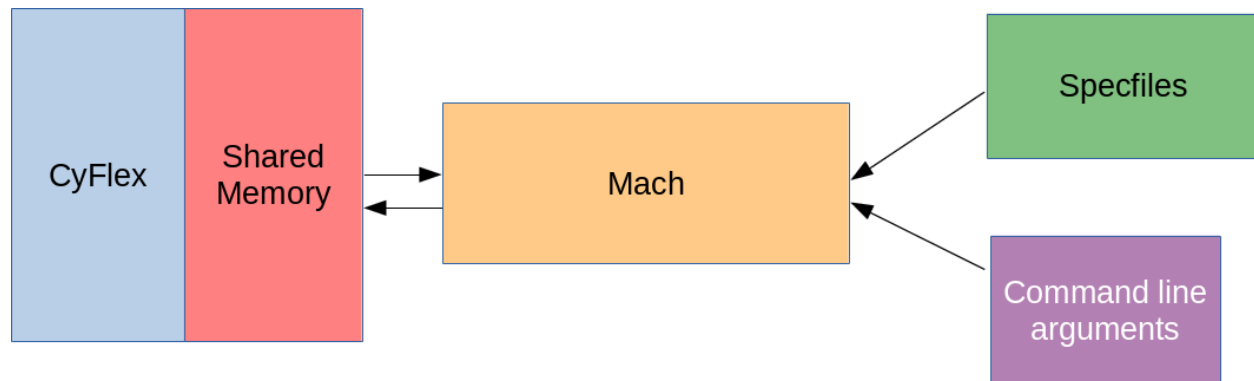
1.1 CyFlex Installation

Install this application from an RPM, `mach_for_cyflex-cummins.rpm`. Use the usual CyFlex update process to get it. If it is no longer needed, it may be uninstalled.

1.2 Mach for CyFlex Configuration

After installation, review or create the following two files:

1. Review the file `/specs/mach_cyflex_properties.txt`. This has several spec file settings which will need to be changed. The first configures Mach for CyFlex to the specific test cell it is running on. See *Appendix A* on page 12 for details on this file.

2. Create a retrieval list file. This specifies the calculations that Mach is to perform and the CyFlex variables that the calculation results are to go into. In this file, blank and comment lines beginning with a sharp (#) character, are ignored. Other lines should be a CyFlex variable name, at least one space and then a Mach retrieval string. The full range of Mach retrieval capability is available including expressions, Mach functions and so on.

This retrieval file could be thought of as a DARTS / Mach retrieval file but with each line prepended with a CyFlex variable name.

Contents of the file would probably be determined in consultation with the engineer(s) requesting the test being run at the test cell.

See *Appendix B* on page 14 for an example retrieval file.

1.3 Mach Diagnostics

The ability to diagnose Mach calculation failures is also available at the test cell. Use the CyFlex command `mach_cyflex_diagnose` to run this application. Entering a keyword will produce HTML output which shows how the calculation is being performed and if the calculation fails, why it fails.

1.4 Mach Setup Assistance Overview

The Mach setup assistance program can help in setting up a test cell. At times a test cell has taken data and the person requesting the test finds that not everything needed for the analysis to perform was sent to DARTS. Then, either the test has to be re-run or the user has to find some way of dealing with the missing data.

If a Mach / DARTS retrieval list is available before testing starts, this can be used to ensure the test cell is set up to take all the data needed to produce everything in the retrieval list. This can then be used at the test cell by checking the retrieval list against the CyFlex configuration files for sending data to DARTS. If the program reports any issues, the configuration files can be updated and the program run again to see if all issues have been resolved.

Refer to *Section 3 Mach Setup Assistance* on page 5 for details.

1.5 Mach Data Checking Overview

While checking a test cell's setup using Mach data assistance, a final check can be done using the Mach data checking program. This program gathers data at the test cell, takes that plus the supplied Mach / DARTS retrieval list and sends this to Mach to perform the retrieval. It then displays the retrieval results, highlighting any issues and offers the option of getting Mach diagnose information to help resolve any remaining issues.

Refer to *Section 4 Mach Data Checking* on page 8 for details.

2   Mach on CyFlex

2.1 Mach Calculations

The full calculation capabilities of Mach can be available at the test cell. Calculations can be performed while an engine is running and results saved in CyFlex variables. These results can be used anywhere CyFlex variables can be used. So, Mach calculated results can be used in limit checks, in CyFlex displays, in `gp_test` scripts and so on. This is referred to as pseudo-real-time mode. Mach will not run at real-time speeds but will run while a test cell is operating in real-time mode.

In addition to pseudo-real-time mode, this can be run in fuel log mode, performing calculations, and adding them to the CyFlex fuel log file.

2.2 Fuel Log Mode

Running Mach in fuel log mode creates calculations which may be appended to the fuel log file. This application has another mode intended for use with CyFlex fuel log file creation. If unfamiliar with fuel logs, go to https://cyflex.com/wp-content/uploads/@FR_LOG_FILE-Specify-Data-File-for-Logging-Fuel-Readings.pdf for details.

 When CyFlex generates a PAM or DARTS data-point in this mode, it will also generate a Mach event. Mach will respond to this event by reading the PAM or DARTS data-point file to get input, measured data. It will then perform any requested calculates and store the results in the CyFlex variables specified in the Mach retrieval list file. Mach will then emit an event to indicate it has completed its work.

To run Mach on CyFlex in fuel log mode, three additional properties are required for the Mach spec file. See *Appendix A* on page 12 for details.

2.3 Mach Operations

When Mach for CyFlex starts up it creates a log file, `/data/errors/mach.log.YYMMDD`, where `YYMMDD` is the usual year, month, day the process was started. This continues as the log file until the process is restarted.

While users are not expected to need this feature, it is possible to run Mach for CyFlex without a running CyFlex system. This is mainly intended for development and testing. Use this feature by specifying two `control_mach start` arguments. The first argument is `-test` and the second is a test data file containing values intended to be used as "measured" data. For example:

```
start_mach_for_cyflex -test ~/measured_values.txt
```

starts the process using the values in the specified file rather than connecting to CyFlex to get measured data. This means that the measured data will not change from iteration to iteration, but for testing purposes this probably won't matter. See *Appendix C* on page 15 for a sample `measured_values.txt` file.

2.4 Mach Performance

Mach will never perform at real-time rates. This is why this is referred to as pseudo-real-time. But it should perform fast enough to be useful while an engine is running. The actual performance depends on a number of factors such as the number of measured channels which

Mach needs to input for each calculation, the number of requested calculations and the update rate.

The update rate is specified in the Mach for CyFlex configuration file as property `com.cmx.mach.cyflex_interval_ms` is the time between the end of one calculation cycle and the beginning of the next calculation. So, there is always this amount of time that Mach is not active. Since this is a low priority task, attempting to perform calculations at a fixed, constant rate might lead to calculation intervals overrunning each other. Refer to *Appendix A* on page 12.

2.5 Mach Command Options

Use the `control_mach` command to manage processing. Enter `control_mach` to display available command line options. Enter `control_mach` *OPTION* to perform any of these. The command accepts one option at a time. The following options are available for this command:

Option	Description
start	Start process execution
stop	Terminate the running process.
restart	Restart the running process. For example, if a referenced spec file has been changed. Running this is similar to running `control_mach stop` followed by `control_mach` start.
pause	Pauses processing and idle the task. This will free up system resources. For example, if a compute intensive task needs all the processing it can get. When done pausing, `control_mach restart` may be run.
report	Produce a one-time output of performance information to the log file. This information includes the average elapsed time and the average CPU time the process spent performing its base function. A rolling set of up to 100 iterations is maintained to product this information.
statistics_off	Turn off the collection of statistics for the `report` option. There is a small performance improvement in doing this.
statistics_on	Turn on the collection of statistics for the `report` option. There is a small performance hit in doing this.

3 Mach Setup Assistance

The information in this section is also available from the program's **Help → Help** option.

This program is intended to assist in set up of test cells with an eye toward being able to perform successful Mach retrievals. The program may operate in any of three modes.

Figure 2 shows the user interface as it would appear at a test cell.

Figure 2: Mach Setup User Interface

3.1 Available Mach Setup Outputs

For a list of measured keywords and parameters find calculated keywords: Select this option and input measured and parameter information to return a list of all keywords which can be calculated from them.

For a Mach retrieval list find what measured keywords and parameters are needed*:* Select this option and input a retrieval list to return a list of parameters and channels which are needed to be able to produce the retrieval list.

For specified retrieval list and measured keywords and parameters see if they agree*:* Select this option and input both a Mach retrieval list and a list of parameters and measured keywords and see if the retrieval list can be produced from the list of parameters and measured keywords. This will produce a list of parameters and measured channels which need to be added to the inputs to retrieve everything in the retrieval list.

3.2 Available Mach Setup Inputs

Input fields are enabled or disabled depending on the output requested.

Engine Configuration (UUT)*:* This field is required for all outputs. Click the dropdown and select from the list of available UUTs. The selection list is in the form `Mach.CONFIGURATION.revision.` CONFIGURATION is typically the `AIR_CONF` parameter value.

Retrieval list: Specify a CyFlex or Mach retrieval list including keywords and expressions. Use the **Search** button to find and select a retrieval list. This is required if the **For a Mach retrieval list find what measured keywords and parameters are needed** and **For specified retrieval list and measured keywords and parameters see if they agree** output options are selected.

CyFlex Format and **Mach Format** are identical except that CyFlex format has CyFlex labels in front of every retrieval item.

One of the following must be specified if the **For a list of measured keywords and parameters find calculated keywords** and **For a Mach retrieval list find what measured keywords and parameters are needed** output options are selected. These files may contain blank or comment lines. Comment lines are lines where the first character is a sharp (#) sign.

These inputs need to come up with a set of parameters and a set of measured channels. These will then be input to the selected output processing.

- **Keyword list** – A file containing one parameter or channel keyword per line. This file contains both parameter and channel information so only the one file is needed. This is mainly intended for test / development use. But other uses may be found over time. Use the **Search** button to find and select a keyword list.

- **DARTS data-point file**: A standard DARTS data-point file which might be sent for loading into DARTS. This file contains both parameter and channel information so only the one file is needed. Use the **Search** button to find and select a file.

- **DARTS spec file**: A standard CyFlex DARTS specification file. This will contain the needed channel information. This also requires an engine specifications (`engine_specs`) file to get the needed parameter information. Use the **Search** button to find and select a file.

- **PAM spec file**:A standard CyFlex PAM specification file. This will contain the needed channel information. This also requires an engine specifications (`engine_specs`) file to get the needed parameter information. Use the **Search** button to find and select files.

3.3 Mach Setup Processing

Select the **Submit** button after completing selections to invoke the selected processing. Input files will be checked that they exist and are readable. Then all the needed files are input and the processing performed. The resulting information is displayed in a separate dialog.

By inputting files every time the button is pressed, they may be edited and saved separately from this program. Pressing the button again will re-input the files and repeat processing with the updated versions of the files.

Refer to *Section 4 Mach Data Checking* on page 8 to do an actual retrieval.

3.4 Disclaimer

In Mach some keywords have various ways they can be calculated. Where appropriate, this program assumes the most common calculation. For example, if a calculation specifies `missingValue(DRY_TO_WET_G1*EXH_CD_CO2_MEA, EXH_CW_CO2_MEA)` this will specify that `EXH_CD_CO2_MEA` is preferred rather than `EXH_CW_CO2_MEA`. Therefore, while this program can provide assistance setting up for Mach retrievals, it is not necessarily definitive. A standard set-up process should include a step of actually retrieving data and ensuring that desired results are available.

4   Mach Data Checking

The information in this section is also available from the program's **Help → Help** option.

This program gives users a chance to check their Mach calculations without having to send data to a database. The data at a test cell may be directly used in this checking.

Figure 3 shows the user interface as it would appear at a test cell.

Figure 3: Mach Data Checking User Interface

4.1 Main Mach Data Checking Inputs

UUT for standard checks: Click the dropdown and select the UUT to use to find suitable standard check sets. his field is required for all outputs. Click the dropdown and select from the list of available UUTs. The selection list is in the form `Mach.CONFIGURATION.revision`. `CONFIGURATION` is typically the `AIR_CONF` parameter value.

Data check-sets: . Select **Enter/Edit** and specify check-set(s). Check sets are groups of Mach logical functions. As part of the retrieval these checks may be performed and any failures in their checking will be reported as part of the output. This information is optional. See *Section 4.3 User Check File* on page 10 for details on entering and editing check-sets

Data check-sets come in two forms: user-specified and standard.

- **User Check Files**: Specify zero or more check set files. These must be in the correct format. See *Section 4.3 User Check File* on page 10 for details on this file format. Use the **Remove** button to remove any selected check set files in the list. Use the **Add** button to get a file dialog to add a check set file.

- **Standard Check Sets**: Some check sets are predefined. Some of these are global and apply to every UUT. The remainder are specific to a UUT. Check boxes are available for each of these check sets to enable or disable specific checks.

Save and **Cancel** Buttons: Click **Save** to save any changes you made. Click **Cancel** to discard changes.

Retrieval list: Specify a CyFlex or Mach retrieval list which may include keywords, expressions, functions, aliases, and so on. This is required. Use the **Search** button to find and select a retrieval list.

CyFlex Format and **Mach Format** are identical except that CyFlex format has CyFlex labels in front of every retrieval item.

Select one of the following input data options:

- **DARTS data-point file**: Select a data file which might be input to DARTS. It is characterized by `$Type, $FixedMetaData, $MetaData, $Measured` sections, and so on. Use the **Search** button to find and select a file.
- **Mach CSV file**: Select a CSV in Mach format. See *Section 4.4 Mach CSV File* on page 10 for details on this file. Use the **Search** button to find and select a file.
- **PAM data-point file**: Data files which might be input to DARTS. Two files must be entered, a data-point file and a header file. Use the **Search** button to find and select a file.

Submit: Select to validate the inputs and then perform the retrieval. See *Section 4.2 Mach* Data Checking Results below for the output produced.

4.2 Mach Data Checking Results

After clicking **Submit** if there are no issues a message will be displayed stating as such. However, if there were issues in the retrieval the following dialog options are displayed:

- **Invoke Mach diagnose on**: Enter a valid parameter or channel keyword into the text area available then click **Submit**. Mach diagnostics will be invoked with the data and the results displayed in a browser.
- **Check Failures**: Any check which generated "false" results will be displayed in this list.
- **Data Retrieval Failures**: If there were failures in the retrieval list they will be displayed in this list. A retrieval failure is indicated by the flag for a retrieval item being `UNAVAILABLE`" or the value `1e31`.

  In either case, if there are no failures of that type, `None` will be displayed.

4.3 User Check File

The following shows an example user check file:

```
# This is a user check set
@CHECK_SET_NAME
Check2
# Here are the actual checks.
@CHECKS
GT(POINT(NONE), 0)
GT(ENG_SPD(RPM), 0)
TRUE()
FALSE()
```

Note that blank lines and comment lines are permitted. Comment lines must begin with a sharp (#) character.

`@CHECK_SET_NAME` must be followed by a name to identify this group of checks.

`@CHECKS` should be followed by lines of Mach logical functions. See the Mach documentation for details on logical functions.

4.4 Mach CSV File

The following shows an example Mach CSV file:

```
POINT,AIR_CONF,FUEL_RATE,ENG_SPD,ENG_TORQ
NONE,NONE,LB/HR,RPM,N-M
STORED_VALUE,STORED_VALUE,RECALC_DRIVEN,STORED_VALUE,PERM_OVERRI
D 1,3,1,1000,6
2,3,2,1000,7
3,3,3,1000,8
4,4,4,1000,9
```

This is identical to the Mach output format. So, a Mach output file could be used as a CSV input file.

The first line of the file should be valid keywords, comma separated.

The second line of the file should be valid units of measure corresponding to the keywords in the first line, comma separated.

The third line should be flag values. These can all appear in Mach retrieval output files. Valid flag values are:

- TYPE_B_UNCERTAINTY
- CONSTANT
- UNITS_CONFLICT
- DERIVED_FROM_USER_OVERRIDE
- TEMP_OVERRIDE
- DERIVED_FROM_TEMP_OVERRIDE

- SPC_RESULTS
- UNCERTAINTY
- RECALC_DRIVEN
- USER_OVERRIDE
- PERM_OVERRIDE
- DERIVED_FROM_PERM_OVERRIDE

- CALCULATED
- AGGREGATED, STORED_VALUE
- PARTIALLY_AGGREGATED
- UNAVAILABLE.

For manually created Mach CSV files, the most likely flag will be STORED_VALUE.

Appendix A - /specs/mach_cyflex_properties.txt

```
# Properties used in Mach for CyFlex

# Mach retrieval items to be retrieved and their mapping to CyFlex
# variables.
com.cmx.mach.cyflex_retrievals /specs/mach_retrieval_list.txt

# Interval between calculation iterations in milliseconds
com.cmx.mach.cyflex_interval_ms 5000

# Engine specs file for getting parameter information from.
com.cmx.mach.eng_specs /specs/engine_specs.TESTCELL

# DARTS specs file for getting channel information from.
# Either this or com.cmx.mach.pam_specs file must be specified.
# If both are specified this takes precedence over the PAM spec file.
com.cmx.mach.darts_specs /specs/darts_specs.TESTCELL

# PAM specs file for getting channel information from.
com.cmx.mach.pam_specs /specs/pam_specs.TESTCELL

# Standard specfilegui properties - typically /cell/cui_properties.txt
com.cmx.mach.specfilegui /cell/cui_properties.txt

#****************************************************
# Entries below here probably do not need to be edited.

# Stop file - existence of this file will terminate the process.
com.cmx.mach.cyflex_stop_file /tmp/stop_mach_for_cyflex

# Restart file - existence of this file will restart the process for
# example if spec files were edited.
com.cmx.mach.cyflex_restart_file /tmp/restart_mach_for_cyflex

# Pause file - existence of this file will pause the process until a
# restart file is created.  This would leave the process running but
# idle, for example if engine changes are made.
com.cmx.mach.cyflex_pause_file /tmp/pause_mach_for_cyflex

# Report file - existence of this file will output a one-time report
# of statistics information to the log file.
com.cmx.mach.cyflex_report_file /tmp/report_mach_for_cyflex

# Statistics on file - existence of this file will start gathering
# datafor use with the report feature.
com.cmx.mach.cyflex_statistics_on_file
/tmp/statistics_on_mach_for_cyflex
```

```
# Statistics off file - existence of this file will terminate
# gathering data for use with the report feature.  There is a small
# performance improvement with this off.
com.cmx.mach.cyflex_statistics_off_file
/tmp/statistics_off_mach_for_cyflex


#******************************************************************
*
# Properties for CyFlex fuel log file operations.  If these properties
# are present, Mach for CyFlex will run in fuel log mode.  Without
# them it will run in pseudo-realtime mode.
# Note that the values specified here are examples only.  CyFlex
# installation will determine the correct values.

# Event which starts Mach processing of a data-point file
com.cmx.mach.fuel_log_start_event FUEL_LOG_START

# Event which Mach emits when it has completed the datapoint
# processing
com.cmx.mach.fuel_log_finished_event FUEL_LOG_FINISHED

# Location of the data-point file, PAM or DARTS format
com.cmx.mach.fuel_log_datapoint_file /data/darts/data-point.txt
```

Appendix B - /specs/retrieval_list.txt

This file could be a standard Mach retrieval list as might be used with DARTS. The one difference is that each retrieval line must be preceded by a retrieval target, a CyFlex variable name and optionally units of measure.

The retrieval target may be a CyFlex variable name. In this case the variable must already exist. If the retrieval target includes a units of measure, variable(units), then the variable may or may not exist. If it doesn't exist, it will be created. If the variable already exists the units of measure must agree between what the CyFlex variable specifies and what the retrieval target specifies.

Mach for CyFlex will not retrieve data for ECM parameters or Auxiliary Keywords. To be able to send these values to DARTS, they must already be in CyFlex variables. So, there would be no point having Mach get values for these from CyFlex and then retrieving them to another or the same CyFlex variable.

For performance reasons the retrieval list should be kept as short as possible. This is another reason ECM and Auxiliary Keywords are not supported. But even allowed retrievals should be kept as limited as possible.

Note in the example below that `my_brk_pwr` must already exist as a CyFlex variable. But `my_m3s` and `my_rpm` may already exist but must be in units or MM3 and RPM respectively. If these variables do not already exist, they will be created.

Mach and CyFlex use different conventions for indicating the units of measure associated with a keyword. Mach uses parenthesis and CyFlex uses square brackets. This program accepts either for the CyFlex variable or for the Mach retrieval items. It does not differentiate mixing and matching. It translates square brackets to parenthesis internally and processes that form.

```
# This is an example of a retrieval list for Mach for CyFlex.
# The first name on a line is the CyFlex variable, the remainder of
# the line is the Mach retrieval item.

# My local brake power
my_brk_pwr BRK_PWR

# My cubic mil stroke
my_m3s[MM3] CUBMILSTROKE

# Getting an expression
my_rpm(rpm) (ENG_SPD(RPM) + RA_SPD[RPM])/2.
```

Appendix C Measured Data File

When running Mach for CyFlex in test/development mode a "measured" data file must be created. Since the file is not intended for common use, it is very simple. The first set of lines are string variable names followed by string values in single or double quote marks. A blank line separates string values from numeric values. Numeric values are a variable name, a blank, a numeric value, a blank and a units of measure. Refer to the following example:

```
model "Coloarado_6LTAA"
serial '74589036'
program "CLRD"
group '-'
MODE "-"

ac_air_ot_p -0.013843001879185302 kpa
air_mtr0_p -0.024920170580828623 kpa
...
F_CO2 0.072467082 pct
```