SYSTEMA PLUMFLOW INTERFACE

Version 4.9.1

User Manual

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All suggestion or error concerning the software or this software manual can be sent to:

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TABLE OF CONTENTS

1 Introduction

The objective of the PLUMFLOW software is to compute the flow field issued from a thruster in vacuum, that is to say:

- Chemical composition of the gas in the chamber and in the plume,
- Physical properties of the gas: viscosity, heat capacity, g, species diameter…
- If necessary, description of the non-gaseous phase : particles or droplets,
- Properties of the plume along the streamlines (velocity, density, pressures…),
- Characteristics of the engine (thrust, mass flow rate…).

This calculation involves a large panel of different methods:

- The computation of the chemical composition and physical properties is performed under assumption of thermodynamic equilibrium.
- The computation of the flow inside the engine and its expansion in the surrounding space uses the method of characteristics or Navier-Stokes equation resolution. These programs perform the simulation of the boundary layer expansion at the nozzle lip.
- The extension of the flow-field beyond the Navier-Stokes and the Method of Characteristics computational domain uses the source-flow method, considering the expansion as isotropic.
- Other methods can be used to handle more specific problems like Direct Simulation Monte-Carlo at the nozzle lip or droplets propagation.

The purpose of this module is to use the Systema interface to run V3 Plumflow applications, which predicts the plume flow field of every kind of thrusters (mono and bipropellant, cold gas and solid). The main interest of the procedure is to keep track of the run executed. Indeed a traceability of the different and repeated runs is available.

The Plumflow interface works as any V4 systema applications, with boxes corresponding to the different processes available: ODE, CEC, Navier, MCLIP, Matlfow, PROLOG, DROPLET, Tecplot converter and Paraview converter. The theoretical aspects of the different computation modules (ODE, CEC, NAVIER, MCLIP, MATFLOW, PROLOG and DROPLET) are not described in this document but in the module dedicated user manuals.

In the following sections, good practice tips are given, and the list of the different I/O files is given per process. For details about the content of each I/O files, please refer to the dedicated user manual.

2 Plumflow Input and Output

2.1 Overview

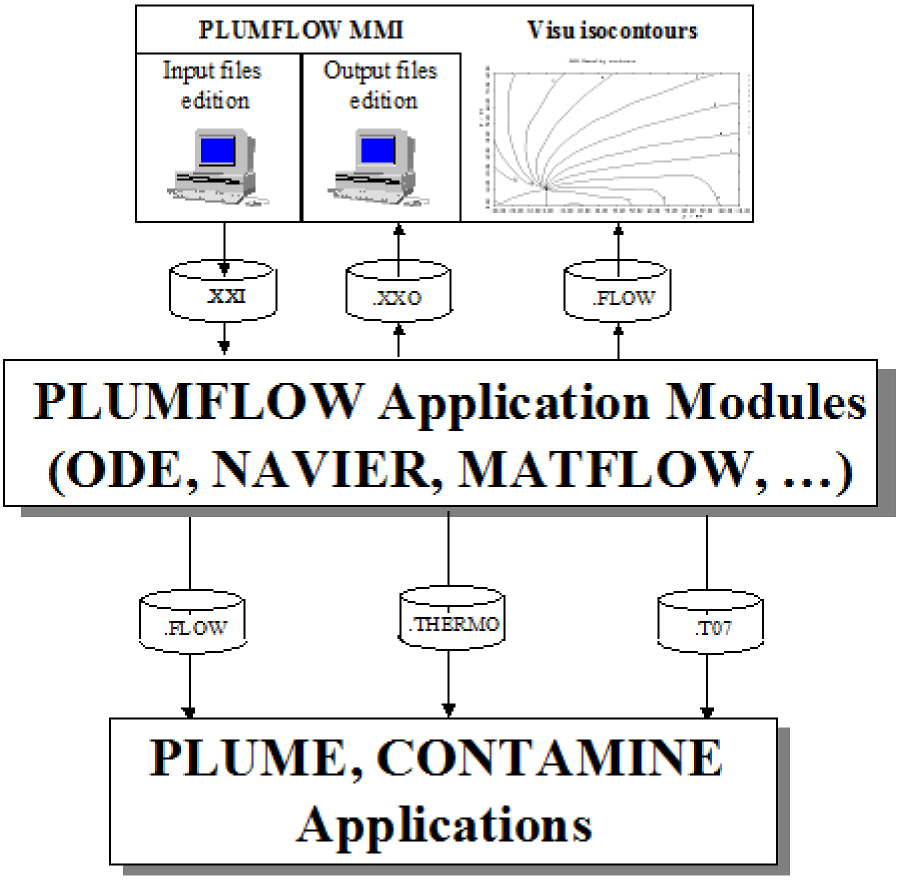
The PLUMFLOW main input files are presented below.
Some additional files can be used by the different computation modules (please refer to the dedicated documentation):

File	Function
"thruster".XXI	Module input file (the two first digit refer to the module : e.g. OD for the ODE module, NS for the NAVIER module)

The PLUMFLOW main output files are:

File	Function
"thruster".XXO	Module output file (the two first digit refer to the module : e.g. OD for the ODE module, NS for the NAVIER module)
"thruster name".FLOW	Flow field description
"thruster name".THERMO	Thermodynamic properties file
"thruster name".T07	Species properties file

All these files are presented on the following figure:



2.2 .XXI file

This file contains the input parameters of the different computation modules. It is generally a namelist file. The extension ended by an "I", is related to the module which reads the file. The list of input file extension is given below.

Module	Extension
ODE	.ODI
CEC	.CEI
TPPLUME	.TPI
NAVIER	.NSI
MCLIP	.MLI
MATFLOW	.MFI
PROLOG	.PRI
DROPLET	.DRI

2.3 .FLOW file

This file contains the characteristics (density, temperature, velocity) of the flow field around the thruster.

2.4 .THERMO file

This is the interface file to ODE. It contains the thermodynamic characteristics of the gas (H, W_{mol}, γ, T, P, Cp, μ, Pr).

2.5 .T07 file

This file contains the thermodynamic characteristics (mass, molar fraction, cross section, number of degrees of freedom) of each group of species. It can be created by the CEC module or by the ODE module (nevertheless, the normal way is to use the CEC module to control the content of the .T07 file).

2.6 .XXO file

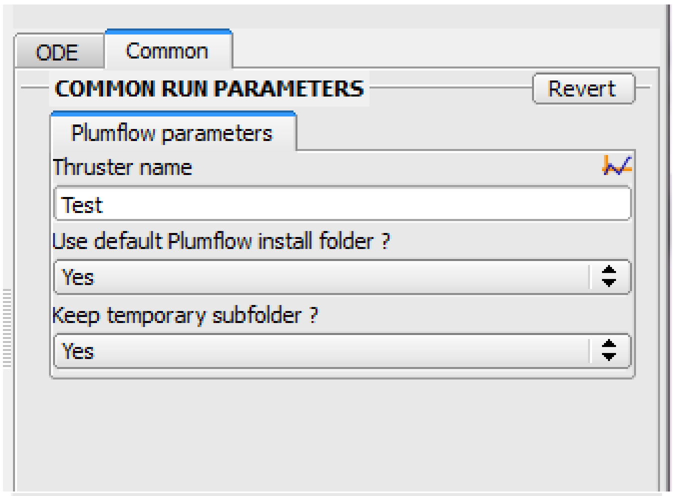
This file is a listing file containing the main results of the different PLUMFLOW computation modules. The extension ended by an “O”, is related to the module which writes the file. The list of output file extensions is given below.

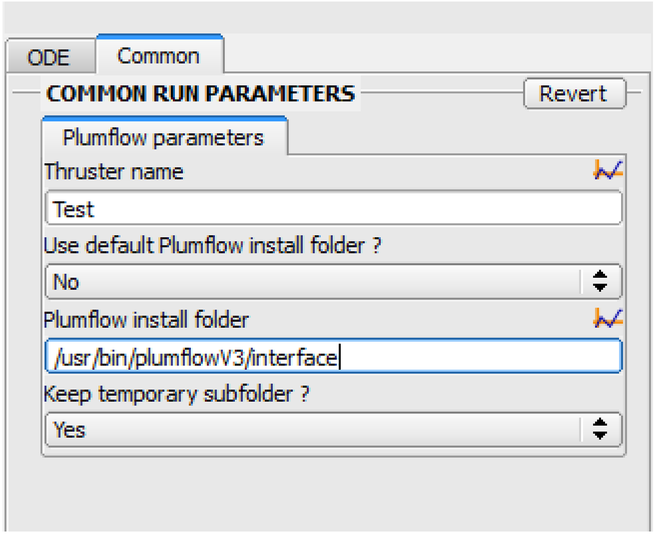
Module	**Extension**
ODE	.ODO
CEC	.CEO
TPPLUME	.TPO
NAVIER	.NSO
MCLIP	.MLO
MATFLOW	.MFO
PROLOG	.PRO
DROPLET	.DRO

3 Good practice advices

A few tips are suggested here for a better use of the software. In any modules of the PLUMFLOW INTERFACE, there is a common tab:

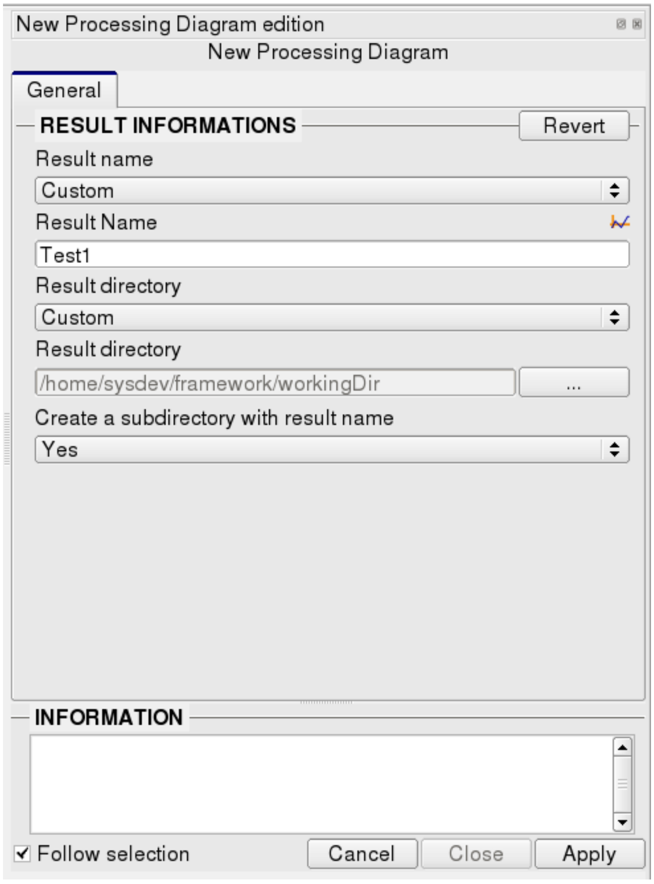
- Thruster name: Define the name of the thruster used for the output file.
- Plumflow install folder: Define the path to the V3 binaries for execution. Since Systema 4.9.1, V3 binaries are installed in the Plumflow Interface install folder that is used as the default path.
- Keep temporary subfolder: Keep or not the intermediate files.





It is also recommended to create a custom name and repository, by clicking on the Edit box on the bottom of the process window.

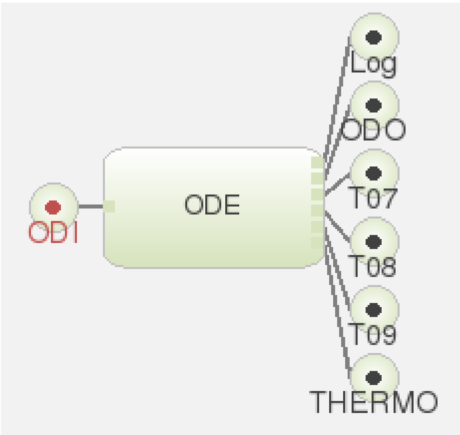
This opens a new tab that allows modification of the name and working repository.


New Processing Diagram edition
New Processing Diagram
General
RESULT INFORMATIONS
Revert
Result name
Custom
Result Name
Test1
Result directory
Custom
Result directory
/home/sysdev/framework/workingDir
...
Create a subdirectory with result name
Yes
INFORMATION
Follow selection
Cancel
Close
Apply

4 Modules

4.1 ODE

The ODE code provides an analytical tool to compute the equilibrium chemical composition of the products in the combustion chamber and the nozzle for a liquid or solid-propellant rocket engine.
In addition, it computes some theoretical thermodynamic properties of the equilibrium mixture.



4.1.1 Inputs

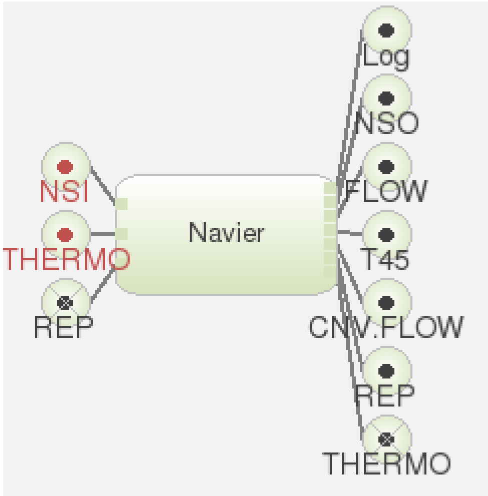
- ODI - ODE input file given by the user.

4.1.2 Outputs

- Log - log file of the processus execution.
- ODO - ODE output file.
- T07 - Interface file to MCLIP and CONTAMINE V3 .
- T08 - Interface to TPPLUME V3.
- T09 - Equivalent to THERMO output file.
- THERMO - Interface file to SESJET, NAVIER MATFLOW and PLUME.

4.2 Navier

The NAVIER code provides a numerical solution for the subsonic / supersonic, axisymmetrical, flow-field inside the nozzle and in its vicinity.



4.2.1 Inputs

- NSI - Navier input file given by the user.
- THERMO - Interface file from ODE.
- REP - Automatically generated by the module to restart an on-going computation.

4.2.2 Outputs

- Log - log file of the processus execution.
- NSO - Navier output file.
- FLOW - Interface file to MCLIP, PROLOG and TRAJET V3.
- T45 - Interface file to MATFLOW.
- CNV.FLOW - Interface file to TRAJET V3.
- REP - Automatically generated by the module to restart an on-going computation.
- THERMO - Interface file to SESJET, NAVIER MATFLOW and PLUME .

4.3 CEC

The CEC module is dedicated on the one hand to the management of groups of species, and on the other hand to the creation of thermodynamic files containing the characteristics of the groups of species.

4.3.1 Inputs

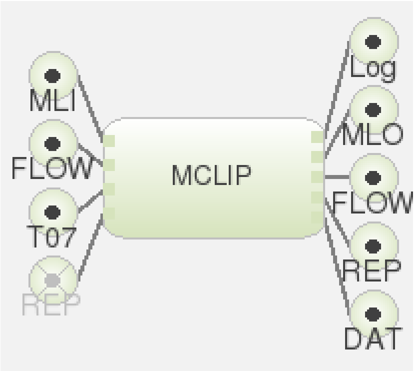
- CEI- CEC input file given by the user.
- T07 - Interface file from ODE.

4.3.2 Outputs

- Log - log file of the processus execution.
- CEO - CEC output file.
- T07 - Interface file to MCLIP and CONTAMINE .

4.4 MCLIP

The objective of the MCLIP module is to compute the thruster flow field at the vicinity of the nozzle lip. In this region the flow passes rapidly from a continuum regime inside the nozzle to a free molecular regime outside. Moreover, the flow around the lip has a strong influence on the backflow and so on the contamination of surfaces located in this region.



4.4.1 Inputs

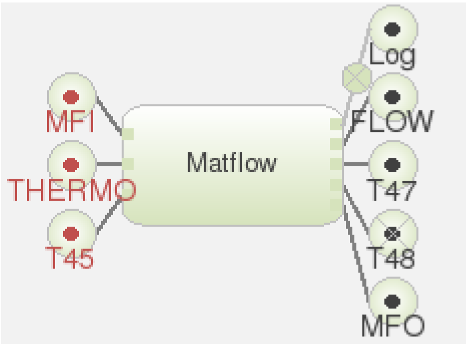
- MLI- MCLIP input file given by the user.
- FLOW - Interface file from Navier.
- T07 - Interface file from ODE or CEC.
- REP - Automatically generated by the module to restart an on-going computation.

4.4.2 Outputs

- Log - log file of the processus execution.
- MLO - MCLIP output file.
- FLOW - Interface file to MCLIP, PROLOG and TRAJET V3.
- REP - Automatically generated by the module to restart an on-going computation.
- DAT -tecplot file to check the mesh generated by MCLIP.

4.5 Matflow

The MATFLOW computer program is used to extend the expansion of the gas/particles plume from the TPPLUME or NAVIER computation domain to the 'infinity'.



4.5.1 Inputs

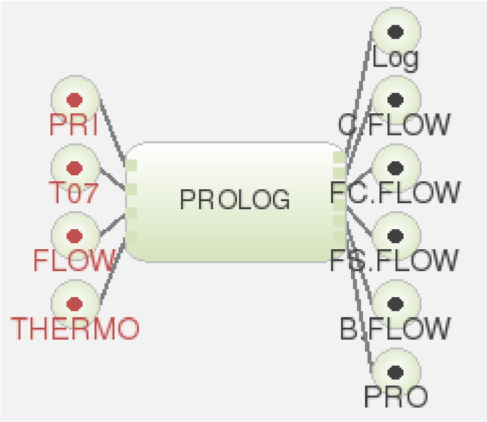
- MFI- Matflow input file given by the user.
- THERMO - Interface file from ODE.
- T45 - Interface file to Navier.

4.5.2 Outputs

- Log - log file of the processus execution.
- FLOW - Interface file to MCLIP, PROLOG and TRAJET V3.
- T47 - Interface file to TRAJET V3.
- T48 - Interface file to PLUMRAD V3.
- MFO - Matflow output file.

4.6 PROLOG

The PROLOG computer program is used to extend the gas flow from the NAVIER or MCLIP computation domain to the 'infinity' and taking into account the different flow regimes.



4.6.1 Inputs

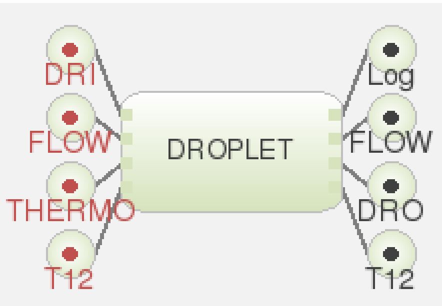
- PRI - PROLOG input file given by the user.
- T07 - Interface file from ODE and CEC.
- FLOW - Interface file from Navier or MCLIP.
- THERMO - Interface file from ODE.

4.6.2 Outputs

- Log - log file of the processus execution.
- C.FLOW - continuum regime flow.
- FC.FLOW - free molecular regime flow in a Cartesian mesh.
- FS.FLOW - free molecular regime flow in the streamlines-based mesh.
- B.FLOW - bridging flow.
- PRO - PROLOG output file.

4.7 DROPLET

The objective of the DROPLET module is to compute the flow of droplets or particles inside and outside a thruster.



4.7.1 Inputs

- DRI - DROPLET input file given by the user.
- FLOW - Interface file from Navier or MCLIP.
- THERMO - Interface file from ODE.
- T12 - Interface file from an to DROPLET.

4.7.2 Outputs

- Log - log file of the processus execution.
- FLOW - Interface file to MCLIP, PROLOG and TRAJET V3.
- DRO - DROPLET output file.
- T12 - Interface file from an to DROPLET.

4.8 Tecplot Converter

Converts the FLOW file into .dat ASCII format.

4.8.1 Input

- FLOW - Interface file from Navier or MCLIP.

4.8.2 Outputs

- Log - log file of the processus execution.
- DAT - DAT ASCII file compatible with tecplot.

4.9 Paraview Converter

Converts the FLOW file into .vtk ASCII format.

4.9.1 Input

- FLOW - Interface file from Navier or MCLIP.

4.9.2 Outputs

- Log - log file of the processus execution.
- VTK - VTK ASCII file compatible with paraview