SOFTWARE USER MANUAL

CFDP Simulator
S2G CFDP Link Budget Tool Reengineering

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Document Status Log

Issue	Section	Change Description	Date
1.0		First Document Issue.	15/05/2024
1.1	3	Update Software Environment information.	05/06/2024
	5.1	Update SW Directory structure example.	
	6.4	Remove heavy rain on radome flag from configuration file parameters	
	7	Update output examples	

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1. INTRODUCTION

1.1. Purpose

The objective of this document is to provide the CFDP Simulator Software users all the information needed to understand and correctly use the said software.

1.2. Acronyms and Abbreviations

The acronyms and abbreviations used in this document are the following ones:

Acronym	Description
CCM	Constant Coding and Modulation
CFDP	CCSDS File Delivery Protocol
FSL	Free Space Losses
ITU-R	ITU Radiocommunication Sector
MODCOD	Modulation and Coding Scheme
S2G	Space to Ground
SW	Software
VCM	Variable Coding and Modulation

1.3. Symbols

Symbol	Description	Units
E_s/N_0	Energy per Channel Symbol over Noise Spectral Power Density	dB

2. RELATED DOCUMENTS

2.1. Applicable Documents

The following table specifies the applicable documents that shall be complied with during project development.

Table 2-1: Applicable documents

Reference	Code	Title	Issue
[SOW]	PE-SW-ESA-GS-833	S2G DATA VIEWER / DFLD4S / ESOV EVOLUTION AND MAINTENANCE STATEMENT OF WORK FOR CHANGE REQUEST 1 TO ESA	1.0
[TEP]	S2G-DME-RCR-ECP121	TECHNICAL & ECONOMICAL PROPOSAL	1.A

2.2. Reference Documents

The following table specifies the reference documents that shall be taken into account during project development.

Table 2-2: Reference documents

Reference	Code	Title	Issue
[TR]		Study on Ka-band Propagation and CFDP for Expansion Sentinels: Task 1 Report	1.0

3. SOFTWARE ENVIRONMENT

3.1. Python

Table 3-1: SW Python Version

Version ~~Required~~Used in Development	~~Recommended~~ Version ~~Used~~
3.10.4~~> 3.7.9~~	3.10.12~~4~~

Note - The standard Python 3 version for Ubuntu 22.04 is *3.10.12*.

The SW works with *pyenv* for the Python version used in development. For more information regarding *pyenv* installation and usage follow the link provided in the README file.

3.2. Required Libraries

Table 3-2: SW Python Required Libraries, Modules and Versions

Library	Modules	Version
netCDF4	-	1.6.5~~1.5.6~~
numpy	-	1.23.3~~1.18.1~~
matplotlib	-	3.6.0~~3.3.2~~
pytz	-	2023.4~~2021.3~~
scipy	-	1.12.0~~1.4.1~~
collections	-	-
pylab	text	-
pathlib	Path	-
xml	-	-
glob	-	-
sys	-	-
os	-	-
copy	-	-
multiprocessing	-	-
itertools	repeat	-
pickle	-	-
datetime	-	-
calendar		
csv		

In order to install the required libraries to run this SW (for Ubuntu20.04 or Ubuntu22.04), use the following command, allowing pip to install the referred libraries dependencies if requested:~~Note - The libraries that require a specific version can be installed with the following command:~~

```
pip install -r requirements. txt
```

3.3. Operating System

The OS ~~being~~ used for development is Ubuntu 20.04 and the SW also works in ~~(the use of~~ Ubuntu 22.04. ~~should also be considered).~~

4. REQUIRED INPUTS

In order to run the SW2, some inputs shall be computed previously:

- ITU-R Files
- Time Series

Also, some inputs must be provided to the first modules (as they were in the SW previous versions):

- Input Link Budget Parameters XML
- Mission Link Statistics netCDF file - PDF Elevation
- MODCOD Set XML

Note - These files are packed with the SW (the folder structure of the package can be confirmed in the next section)

5. SOFTWARE USAGE

With the SW Refactoring, the user can now trigger each module individually or choose a set of modules to be triggered sequentially.

5.1. Triggering Modules Separately

In order to trigger each module through command line, the user must indicate the python file name of the desired module followed by the respective configuration file path, as follows:

```
python [module_name]_module.py conf/[module_name]_conf.xml
```

Before triggering each module, the user shall make sure the input file paths and names in each configuration file are correct, since each new module's output file name will have a different datetime in the file name. The output directory for each module is also configurable in the respective configuration file.

Note - The example assumes the user is already in the root directory of the project.

This is the expected directory structure after unpacking the software:

```
.
├── common
│   ├── filename_check.py
│   └── read_auxiliary.py
├── conf
│   ├── atmospheric_attenuation_conf.xml
│   ├── cfdp_statistics_conf.xml
│   ├── global_statistics_conf.xml
│   ├── link_budget_conf.xml
│   ├── link_outages_conf.xml
│   ├── optimization_conf.xml
│   └── orchestrator_conf.xml
├── inputs
│   ├── CO2M_link_statistics.nc
│   ├── input_link_budget_Innuvik.xml
│   ├── input_link_budget_Matera.xml
│   ├── input_link_budget_McMurdo.xml
│   ├── input_link_budget_Neustrelitz.xml
│   ├── input_link_budget_Svalsat.xml
│   ├── input_link_budget_Toulouse.xml
│   └── modcod_set1.xml
├── itur
│   ├── itu_r_p0839_files
│   ├── itu_r_p1510_files
```

```
│   ├── __pycache__
│   ├── __init__.py
│   ├── __init__.pyc
│   ├── Innuvik.mat
│   ├── interp.py
│   ├── itu_r_p0838.py
│   ├── itu_r_p0839.py
│   ├── itu_r_p1510.py
│   ├── Matera.mat
│   ├── McMurdo.mat
│   ├── Neustrelitz.mat
│   ├── Svalsat.mat
│   └── Toulouse.mat
├── outputs
├── TIME_SERIES
│   ├── ITU0
│   ├── ITU1
│   ├── ITU2
│   ├── ITU3
│   ├── ITU4
│   ├── ITU5
│   ├── ITU6
│   ├── ITU7
│   ├── ITU8
│   ├── ITU9
│   └── README_DS3.org
├── atmospheric_attenuation_module.py
├── cfdp_statistics_module.py
├── global_statistics_module.py
├── link_budget_module.py
├── link_outages_module.py
├── optimization_module.py
├── orchestrator_module.py
├── README_detailed_version.docx
├── README.md
└── requirements.txt
```

5.2. Using Software Orchestrator

The Software Orchestrator allows the user to select a set of consecutive modules to be triggered sequentially and can be used in the same way as the rest of the modules:

```
python orchestrator_module.py conf/orchestrator_conf.xml
```

However, the Orchestrator also accepts the following usages:

- Using the *-c* or *--config* flag to provide the Configuration File

```
python orchestrator_module.py [-c Configuration File]
```

- By providing the configuration parameters with the following flags:

```
python orchestrator_module.py [-o Output Directory] [-i Input Directory] [-m Selected Modules]
[-cm Modules Conf Files Dir] [-l Link Availability]
```

- Using the *-h* or *--help* flag provides some more information about each argument accepted, as well as some usage examples:

```
python orchestrator_module.py –help
```

```
usage: orchestrator_module.py [-h] [-c CONFIG] [-o OUTPUT] [-i INPUT] [-m MODULES] [-cm
CONF_MODULES] [-l [LINK_AVAIL]]


options:
  -h, --help            show this help message and exit
  -c CONFIG, --config CONFIG
                        Filepath of Orchestrator's Configuration File
  -o OUTPUT, --output OUTPUT
                        Set Output Path
  -i INPUT, --input INPUT
                        Set Input Path
  -m MODULES, --modules MODULES
                        Set Modules to be triggered by the Orchestrator. [0] Module not
triggered, [1] Module Triggered. Format example: -m 110110
  -cm CONF_MODULES, --conf_modules CONF_MODULES
                        Set Modules' Configuration Files Directory Path
  -l [LINK_AVAIL], --link_avail [LINK_AVAIL]
                        Set Link Availability for the computations. Format example: -l 99.9
97.9 92.0
```

Note - When providing the Configuration File (either using *-c* or not), all the other arguments are not needed and will be discarded. Only the configurations defined by the Configuration File will be considered.

6. MODULES DESCRIPTION

6.1. Atmospheric Attenuation Computation Module

This module is responsible for computing the Atmospheric Attenuation (Total and Clear Sky) and Rain Rate for the provided Link Availability through Configuration File. This module also outputs the Elevation Angles and Average Contact Time parsed from the previously computed PDF Link Statistics.

6.1.1. Configuration

The configurations for this module must be passed through a XML File with the following structure:

Table 6-1: Configuration file elements for the Atmospheric Attenuation Module

Element	Sub-Element	Attribute	Value (e.g.)	Description
Input_Files	*link_budget_parameters*	path		File Path for Link Budget Input Parameters File
	pdf_elevation	path		File Path for PDF Elevation netCDF File
	itur_path	path		Directory Path for ITU-R files
Output_Dir	-	path		Output Directory for Atmospheric Attenuation Computations
Configuration_Parameters	*mission_id*	-	CO2M	Earth observation mission orbit name
	link_availability	-	99.9 99.0 97.5	Array with the Link Availability Values

6.2. Link Budget Module

This module computes the following values, for the provided Link Availability Values:

- Energy per Channel Symbol Over Noise Power Spectral Density Ratio [Es/N0]
- Free Space Losses
- Merit Figure of the Ground Station

6.2.1. Configuration

Table 6-2: Configuration file elements for the Link Budget Module

Element	Sub-Element	Attribute	Value (e.g.)	Description
Input_Files	*link_budget_parameters*	path		File Path for Link Budget Input Parameters File
	atmospheric_attenuation	path	-	Path for input Atmospheric Attenuations and Rain Rate
Output_Dir	-	path		Output Directory for Link Budget Computations
Configuration_Parameters	*heavy_rain_radome*	-	0	Flag that indicates if it is an heavy rain on radome scenario simulation
	link_availabilty	-	99.9 99.0 97.5	Array with the Link Availability Values

6.3. Optimization Module - for Best MODCOD Combinations Computation

This module computes the best MODCOD combination(s) for the available Es/N0 values, outputting the following values per combination:

- Total Data Volume
- Data Volume
- Elevation Angle
- Data Rate
- MODCOD Index
- OBO
- Es/N0

The user is able to select the <u>Adaptation Type</u> in order to compute one (CCM) or more (VCM) MODCOD combinations.

6.3.1. Configuration

Table 6-3: Configuration file elements for the Optimization Module

Element	Sub-Element	Attribute	Value (e.g.)	Description
Input_Files	*link_budget_parameters*	path	-	File Path for Link Budget Input Parameters File
	modcod_set	path	-	Path for MODCOD set file
	link_budget_out	path	-	Path for output of Link Budget Module
Output_Dir	-	path		Output Directory for Best MODCOD Combinations
Configuration_Parameters	*min_elev_angle*	-	5.0	Minimum Elevation Angle
	adaptation_type	-	CCM	Adaptation Type: [CCM] or [VCM]
	n_cores	-	8	Number of cores to be used in Multi-processing computations
	link_availabilty	-	99.9 99.0 97.5	Array with the Link Availability Values

Note - Running this module is optional when running the full chain. The SW is able to compute the Link Outages without the computations of the best MODCOD combination(s).

6.4. Link Outages Computations Module

This module computes the Link Outages for the provided Link Availability values and selected years, also computing the Outage Time Series for the given data.

6.4.1. Configuration

Table 6-4: Configuration file elements for the Link Outages Computations Module

Element	Sub-Element	Attribute	Value (e.g.)	Description
Input_Files	*link_budget_parameters*	path	-	File Path for Link Budget Input Parameters File
	modcod_set	path	-	Path for MODCOD set file
	link_budget_out	path	-	Path for output of Link Budget Module
	best_modcod	path	-	File Path for output of Optimization Module
	time_series_path	path	-	Directory Path for Time Series files
Output_Dir	-	path		Output Directory for Link Outages Calculations
Configuration_Parameters	*max_num_MODCOD*	-	6	Maximum Number of MODCODs to be considered
	~~*heavy_rain_radome*~~	~~-~~	~~CCM~~	~~Flag that indicates if it is an heavy rain on radome scenario simulation~~
	year_analysis	-	2002 2004 2005	Years for Outages Analysis
	link_availabilty	-	99.9 99.0 97.5	Array with the Link Availability Values

Note - If the Best MODCOD file path is provided, the SW considers the Optimization Module was triggered, ignoring the Link Budget Output file. Meaning if a non-Optimization scenario is to be triggered, the *best_modcod* sub-element shall be removed or the "*path*" attribute shall be left empty.

6.5. CFDP Statistics Calculations Module

This module calculates the CFDP Outages Statistics for the previously computed Link Outages.

6.5.1. Configuration

Table 6-5: Configuration file elements for the CFDP Statistics Calculations Module

Element	Sub-Element	Attribute	Value (e.g.)	Description
Input_Files	*link_outages*	path	-	File Path for Link Outages Output File
	outage_time_series	path	-	Directory Path for Outage Time Series files
	time_series_path	path	-	Directory Path for Time Series files
	link_budget_out	path	-	File Path for output of Link Budget Module
	modcod_set	path	-	File Path for MODCOD set
	best_modcod	path	-	File Path for output of Optimization Module
Output_Dir	-	path		Output Directory for CFDP Statistics Calculations
Configuration_Parameters	*cfdp_class*	-		CFDP Class to be computed
	year_analysis	-	2002 2004 2005	Years for CFDP Analysis
	worst_day	-	0	Worst Day Scenario Analysis
	summary_csv	-	1	Flag for writing a summary CSV file with the CFDP Statistics results
	pdu_size	-	65580	Size of PDUs (in bits)
	file_size	-	100	Size of Files (in GB)
	data_rate	-		Data Rate value for CFDP Statistics computations
	timeout	-		Timeout for Class 2 CFDP Computation (in minutes)
	link_availabilty	-	99.9 99.0 97.5	Array with the Link Availability Values

Note - For the Nominal Scenario, only the *link_outages* and the *outage_time_series* are needed. All other parameters are only for computing the Worst Day Scenario, for which the same as the previous module's note applies, on what regards the existence of the *best_modcod* path.

6.6. Global Outages Statistics Calculations Module

This module generates the following plots with all the previously computed data:

- Contiguous Outages Durations per Hour
- Time Percentage of Contact in Outage
- Worst Day Es/N0 Time Series for Year
- Es/N0 against Elevation Angle for Maximum Availability
- Monthly Total Outages Mean and Standard Deviation
- Accumulated Outage Time (in minutes) per ear for CCM
- Elevation Angle per Samples foreach Year
- Completely Lost Passes (if any)
- Total Attenuation against Elevation Angle
- Total Outages for All Years and All Months
- Statistics for Worst Year in terms of Outages
- Yearly Outages in Heavy Rain on Radome scenario — *Not implemented for version 2.0.0*
- Contiguous Outage Durations for Selected Years
- Decomposition of Total Outages

6.6.1. Configuration

Table 6-6: Configuration file elements for the Global Statistics Calculations Module

Element	Sub-Element	Attribute	Value (e.g.)	Description
Input_Files	*link_outages*	path	-	File Path for Link Outages Output File
	atmospheric_attenuation	path	-	File Path for input Atmospheric Attenuations and Rain Rate
	link_budget_parameters	path	-	File Path for Link Budget Input Parameters File
	link_budget_out	path	-	File Path for output of Link Budget Module
	best_modcod	path	-	File Path for output of Optimization Module
Output_Dir	-	path		Output Directory for Global Statistics Calculations
Configuration_Parameters	*link_availabilty*	-	99.9 99.0 97.5	Array with the Link Availability Values
	year_analysis	-	2002 2004 2005	Years for CFDP Analysis
	worst_day	-	0	Worst Day Scenario Analysis
Plots_Selection	*plot*	name	1	Flag for plotting Contiguous Outages Durations per Hour
	plot	name	1	Flag for plotting Time Percentage of Contact in Outage

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plot	name	1	Flag for plotting Worst Day Es/N0 Time Series for Year
plot	name	1	Flag for plotting Es/N0 against Elevation Angle for Maximum Availability
plot	name	1	Flag for plotting Monthly Total Outages Mean and Standard Deviation
plot	name	1	Flag for plotting Accumulated Outage Time (in minutes) per ear for CCM
plot	name	1	Flag for plotting Elevation Angle per Samples foreach Year
plot	name	1	Flag for plotting Completely Lost Passes (if any)
plot	name	1	Flag for plotting Total Attenuation against Elevation Angle
plot	name	1	Flag for plotting Total Outages for All Years and All Months
plot	name	1	Flag for plotting Statistics for Worst Year in terms of Outages
plot	name	0	Flag for plotting Yearly Outages in Heavy Rain on Radome scenario
plot	name	1	Flag for plotting Contiguous Outage Durations for selected years
plot	name	1	Flag for plotting Decomposition of Total Outages

6.7. Orchestrator Module

This module is responsible for orchestrating the rest of the SW Modules. It is able to change the configurations of the modules selected by the user in order to trigger them sequentially. Meaning that **when more than one module is selected, they must be sequential** (except or the Optimization Module, which is optional):

1. Atmospheric Attenuation Computation Module
2. Link Budget Computation Module
3. Optimization Module (optional)
4. Link Outages Computation Module
5. CFDP Statistics Calculation Module

6.7.1. Configuration

Table 6-7: Configuration file elements for the Orchestrator Module

Element	Sub-Element	Attribute	Value (e.g.)	Description
Input_Dir	-	path	-	Input Directory for the modules' input files (e.g. MODCOD Set)
Output_Dir	-	path		Output Directory for the module's output files
Modules	*Atmospheric_Attenuation*	-	1	Flag to trigger the module
	Link_Budget	-	1	Flag to trigger the module
	Optimization	-	0	Flag to trigger the module
	Link_Outages	-	1	Flag to trigger the module
	CFDP_Statistics	-	1	Flag to trigger the module
	Global_Outage_Statistics	-	1	Flag to trigger the module
Configuration_Files		path	-	Path to Configuration Files directory
	Atmospheric_Attenuation	-	atmospheric_attenuation_conf.xml	Module's Configuration File name
	Link_Budget	-	link_budget_conf.xml	Module's Configuration File name
	Optimization	-	optimization_conf.xml	Module's Configuration File name
	Link_Outages	-	link_outages_conf.xml	Module's Configuration File name
	CFDP_Statistics	-	cfdp_statistics_conf.xml	Module's Configuration File name
	Global_Outage_Statistics	-	global_statistics_conf.xml	Module's Configuration File name
Link_Availability	-	-	99.9 99.0 97.5	Array with the Link Availability Values

Some of the configuration parameters can **instead be provided through the command line** as the following example:

```
python orchestrator_module.py -o outputs/orchestrator/ -i inputs/ -m 110111 -cm conf/ -l 99.9
99.0 97.5
```

7. OUTPUT EXAMPLES

In this section are some examples of the expected outputs when triggering certain scenarios.

7.1. Trigger All Modules – CCM Scenario

In this example, the Orchestrator was triggered with the following command:

```
python orchestrator_module.py -c conf/orchestrator_conf.xml
```

And the Orchestrator Configuration File set as follows:

```
<Orchestrator_Module_Configuration>

    <Input_Dir   path="inputs/"/>

    <Output_Dir path="outputs/orchestrator/CCM/"/>

    <Modules>

        <Atmospheric_Attenuation  type="BOOLEAN">1</Atmospheric_Attenuation>

        <Link_Budget              type="BOOLEAN">1</Link_Budget>

        <Optimization             type="BOOLEAN">1</Optimization>

        <Link_Outages             type="BOOLEAN">1</Link_Outages>

        <CFDP_Statistics          type="BOOLEAN">1</CFDP_Statistics>

        <Global_Outage_Statistics type="BOOLEAN">1</Global_Outage_Statistics>

    </Modules>

    <Configuration_Files          path="conf/">

        <Atmospheric_Attenuation
type="STRING">atmospheric_attenuation_conf.xml</Atmospheric_Attenuation>

        <Link_Budget              type="STRING">link_budget_conf.xml</Link_Budget>

        <Optimization             type="STRING">optimization_conf.xml</Optimization>

        <Link_Outages             type="STRING">link_outages_conf.xml</Link_Outages>

        <CFDP_Statistics          type="STRING">cfdp_statistics_conf.xml</CFDP_Statistics>

        <Global_Outage_Statistics
type="STRING">global_statistics_conf.xml</Global_Outage_Statistics>

    </Configuration_Files>

    <Link_Availability type="ARRAY" elementType="FLOAT">99.9 99.0 97.5</Link_Availability>

</Orchestrator_Module_Configuration>
```

Note that what defines this simulation as CCM is the fact that the Optimization Module is triggered with the *<adaptation_type>* parameter set to *"CCM"*.

The expected Logs for the given configurations are the following:

```
Writing Output of Atmospheric Attenuation Computation...

Atmospheric Attenuation Computed Successfully!
```

```
Writing Link Budget Output File...

Link Budget Computed Successfully!


Number of Cores for Multi-processing not defined, using: 8

Writing Optimization Module Output File...

Best MODCOD Combinations Computed successfully!


Computing Link Outages using Best MODCOD Combinations.

Adaptation Type: CCM

Writing Link Outages Output File

Link Outages Computed Successfully!


**WARNING** - CFDP Class to be computed not specified in Configuration File...

Computing both CFDP Classes (1 and 2).

**WARNING** - Data Rate not specified in Configuration File...

Data Rate Default Value is 1600.0

**WARNING** - No Timeout as been defined for CFDP Class 2 computation

A CSV File will be generated with a summary of the CFDP Statistics Computations

Computing CFDP Class 1 and 2 Statistics

Computing CFDP Class 1 and 2 Statistics

Computing CFDP Class 1 and 2 Statistics

Computing CFDP Class 1 and 2 Statistics

Computing CFDP Class 1 and 2 Statistics

Computing CFDP Class 1 and 2 Statistics

Computing CFDP Class 1 and 2 Statistics

Computing CFDP Class 1 and 2 Statistics

Computing CFDP Class 1 and 2 Statistics

CFDP Statistics Computed Successfully!


Plotting Contiguous Outages Durations per Hour

Plotting Time Percentage of Contact in Outage

Plotting Worst Day Es/N0 Time Series for Year

Plotting Es/N0 against Elevation Angle for Maximum Availability

Plotting Monthly Total Outages Mean and Standard Deviation

Plotting Accumulated Outage Time (in minutes) per ear for CCM

Plotting Elevation Angle per Samples foreach Year

Plotting Completely Lost Passes (if any)

Plotting Total Attenuation against Elevation Angle

Plotting Total Outages for All Years and All Months
```

```
Plotting Statistics for Worst Year in terms of Outages

Plotting Contiguous Outage Durations for each Month

Plotting Contiguous Outage Durations for Selected Years

Plotting Decomposition of Total OutagesWriting Output of Atmospheric Attenuation Computation...
Atmospheric Attenuation Computed Successfully!


Writing Link Budget Output File...
Link Budget Computed Sucessfully!


Number of Cores for Multi-processing not defined, using: 8
Writing Optimization Module Output File...
Best MODCOD Combinations Computed successfully!


Computing Link Outages using Best MODCOD Combinations.
Adaptation Type: CCM
Writing Link Outages Output File
Link Outages Computed Successfully!


**WARNING** - CFDP Class to be computed not specified in Configuration File...
Computing both CFDP Classes (1 and 2).
**WARNING** - Data Rate not specified in Configuration File...
Data Rate Default Value is 1600.0
**WARNING** - No Timeout as been defined for CFDP Class 2 computation
A CSV File will be generated with a summary of the CFDP Statistics Computations
Computing CFDP Class 1 and 2 Statistics
Computing CFDP Class 1 and 2 Statistics
Computing CFDP Class 1 and 2 Statistics
CFDP Statistics Computed Successfully!


Plotting Contiguous Outages Durations per Hour

Plotting Time Percentage of Contact in Outage

Plotting Worst Day Es/N0 Time Series for Year

Plotting Es/N0 against Elevation Angle for Maximum Availbility

Plotting Monthly Total Outages Mean and Standard Deviation

Plotting Accumulated Outage Time (in minutes) per ear for CCM

Plotting Elevation Angle per Samples foreach Year

Plotting Completely Lost Passes (if any)

Plotting Total Attenuation against Elevation Angle

Plotting Total Outages for All Years and All Months
```

~~Plotting Statistics for Worst Year in terms of Outages~~

~~Plotting Contiguous Outage Durations for selected years~~

~~Plotting Decomposition of Total Outages~~

The expected directories and files structure after running all modules is the following:

```
outputs/orchestrator/CCM
├── CO2M_Svalsat_CFDP1_2002_20240603141336
│     ├── link_availability_97_5
│     ├── link_availability_99_0
│     └── link_availability_99_9
├── CO2M_Svalsat_CFDP1_2004_20240603141336
│     ├── link_availability_97_5
│     ├── link_availability_99_0
│     └── link_availability_99_9
├── CO2M_Svalsat_CFDP1_2005_20240603141336
│     ├── link_availability_97_5
│     ├── link_availability_99_0
│     └── link_availability_99_9
├── CO2M_Svalsat_CFDP2_2002_20240603141336
│     ├── link_availability_97_5
│     ├── link_availability_99_0
│     └── link_availability_99_9
├── CO2M_Svalsat_CFDP2_2004_20240603141336
│     ├── link_availability_97_5
│     ├── link_availability_99_0
│     └── link_availability_99_9
├── CO2M_Svalsat_CFDP2_2005_20240603141336
│     ├── link_availability_97_5
│     ├── link_availability_99_0
│     └── link_availability_99_9
├── CO2M_Svalsat_GlobalStats_CCM_20240603141336
│     ├── Att_vs_theta_svalsat_for_multiple_avail.png
│     ├── EsNo_vs_theta_svalsat_for_avail_97.50.png
│     ├── EsNo_vs_theta_svalsat_for_avail_99.00.png
│     ├── EsNo_vs_theta_svalsat_for_avail_99.90.png
│     ├── Svalsat_average_monthly_outage_over_3_years.png
│     ├── Svalsat_best_data_volume.png
│     ├── Svalsat_contiguous_outages_duration_for_month_10.png
│     ├── Svalsat_contiguous_outages_duration_for_month_12.png
```

```
│     ├── Svalsat contiguous outages duration for month 5.png
│     ├── Svalsat contiguous outages duration for month 7.png
│     ├── Svalsat contiguous outages duration for month 8.png
│     ├── Svalsat contiguous outages duration for year 2002.png
│     ├── Svalsat contiguous outages duration for year 2004.png
│     ├── Svalsat contiguous outages duration for year 2005.png
│     ├── Svalsat contiguous outages duration.png
│     ├── Svalsat contiguous outages hour day for month 10.png
│     ├── Svalsat contiguous outages hour day for month 12.png
│     ├── Svalsat contiguous outages hour day for month 5.png
│     ├── Svalsat contiguous outages hour day for month 7.png
│     ├── Svalsat contiguous outages hour day for month 8.png
│     ├── Svalsat cumulated yearly outage time.png
│     ├── Svalsat Data volume average passage contact time.png
│     ├── Svalsat data volume best.png
│     ├── Svalsat hour outages year.png
│     ├── Svalsat lost passes.png
│     ├── Svalsat outage elev angle 2002.png
│     ├── Svalsat outage elev angle 2004.png
│     ├── Svalsat outage elev angle 2005.png
│     ├── Svalsat standard deviation mean contact time over ten years.png
│     ├── Svalsat Time percentage the contact in outage.png
│     ├── Svalsat total monthly outage.png
│     ├── Svalsat total yearly outage percentage.png
│     ├── Svalsat worst day EsN0 time series for year 2002.png
│     ├── Svalsat worst day EsN0 time series for year 2004.png
│     └── Svalsat worst day EsN0 time series for year 2005.png
├── CO2M Svalsat AtmosphericAtt 20240603141336.xml
├── CO2M Svalsat BestMODCOD CCM 20240603141336.xml
├── CO2M Svalsat LinkBudget 20240603141336.xml
├── CO2M Svalsat LinkOutages CCM 20240603141336.xml
└── CO2M Svalsat outage time series CCM 20240603141336.ncoutputs/orchestrator/CCM
├── CO2M_Svalsat_CFDP1_2002_20240513152044
│   ├── link_availability_97_5
│   ├── link_availability_99_0
│   └── link_availability_99_9
├── CO2M_Svalsat_CFDP2_2002_20240513152044
│   ├── link_availability_97_5
│   ├── link_availability_99_0
```

```
│   └── link_availability_99_9
├── CO2M_Svalsat_GlobalStats_CCM_20240513152044
│   ├── Att_vs_theta_svalsat_for_multiple_avail.png
│   ├── EsNo_vs_theta_svalsat_for_avail_97.50.png
│   ├── EsNo_vs_theta_svalsat_for_avail_99.00.png
│   ├── EsNo_vs_theta_svalsat_for_avail_99.90.png
│   ├── Svalsat_average_monthly_outage_over_1_years.png
│   ├── Svalsat_contiguous_outages_duration.png
│   ├── Svalsat_cumulated_yearly_outage_time.png
│   ├── Svalsat_Data_volume_average_passage_contact_time.png
│   ├── Svalsat_data_volume_best.png
│   ├── Svalsat_hour_outages_year.png
│   ├── Svalsat_lost_passes.png
│   ├── Svalsat_outage_elev_angle__2002.png
│   ├── Svalsat_standard_deviation_mean_contact_time_over_ten_years.png
│   ├── Svalsat_Time_percentage_the_contact_in_outage.png
│   ├── Svalsat_total_monthly_outage.png
│   ├── Svalsat_total_yearly_outage_percentage.png
│   └── Svalsat_worst_day_EsN0_time_series_for_year__2002.png
├── CO2M_Svalsat_AtmosphericAtt_20240513152044.xml
├── CO2M_Svalsat_BestMODCOD_CCM_20240513152044.xml
├── CO2M_Svalsat_LinkBudget_20240513152044.xml
├── CO2M_Svalsat_LinkOutages_CCM_20240513152044.xml
└── CO2M_Svalsat_outage_time_series_CCM_20240513152044.nc
```

7.2. Trigger All Modules Except Optimization

In this example, the Orchestrator was triggered with the following command:

```
python orchestrator_module.py -c conf/orchestrator_conf.xml
```

And the Orchestrator Configuration File set as follows:

```
<Orchestrator_Module_Configuration>
    <Input_Dir  path="inputs/"/>
    <Output_Dir path="outputs/orchestrator/Non-Opt/"/>
    <Modules>
        <Atmospheric_Attenuation  type="BOOLEAN">1</Atmospheric_Attenuation>
        <Link_Budget              type="BOOLEAN">1</Link_Budget>
        <Optimization             type="BOOLEAN">0</Optimization>
        <Link_Outages             type="BOOLEAN">1</Link_Outages>
```

```
        <CFDP_Statistics           type="BOOLEAN">1</CFDP_Statistics>

        <Global_Outage_Statistics type="BOOLEAN">1</Global_Outage_Statistics>

    </Modules>

    <Configuration_Files          path="conf/">

        <Atmospheric_Attenuation
type="STRING">atmospheric_attenuation_conf.xml</Atmospheric_Attenuation>

        <Link_Budget               type="STRING">link_budget_conf.xml</Link_Budget>

        <Optimization              type="STRING">optimization_conf.xml</Optimization>

        <Link_Outages              type="STRING">link_outages_conf.xml</Link_Outages>

        <CFDP_Statistics           type="STRING">cfdp_statistics_conf.xml</CFDP_Statistics>

        <Global_Outage_Statistics
type="STRING">global_statistics_conf.xml</Global_Outage_Statistics>

    </Configuration_Files>

    <Link_Availability type="ARRAY" elementType="FLOAT">99.9 99.0 97.5</Link_Availability>

</Orchestrator_Module_Configuration>
```

Note that what defines this simulation as CCM is the fact that the Optimization Module is triggered with the *<adaptation_type>* parameter set to *"CCM"*.

The expected Logs for the given configurations are the following:

```
Writing Output of Atmospheric Attenuation Computation...

Atmospheric Attenuation Computed Successfully!


Writing Link Budget Output File...

Link Budget Computed Successfully!


Best MODCOD Combinations File was not provided or does not exist.

Computing Link Outages without optimization.

Writing Link Outages Output File

Link Outages Computed Successfully!


**WARNING** - CFDP Class to be computed not specified in Configuration File...

Computing both CFDP Classes (1 and 2).

**WARNING** - Data Rate not specified in Configuration File...

Data Rate Default Value is 1600.0

**WARNING** - No Timeout as been defined for CFDP Class 2 computation

A CSV File will be generated with a summary of the CFDP Statistics Computations

Computing CFDP Class 1 and 2 Statistics

Computing CFDP Class 1 and 2 Statistics

Computing CFDP Class 1 and 2 Statistics
```

Computing CFDP Class 1 and 2 Statistics

Computing CFDP Class 1 and 2 Statistics

Computing CFDP Class 1 and 2 Statistics

Computing CFDP Class 1 and 2 Statistics

Computing CFDP Class 1 and 2 Statistics

Computing CFDP Class 1 and 2 Statistics

CFDP Statistics Computed Successfully!

Plotting Contiguous Outages Durations per Hour

Plotting Time Percentage of Contact in Outage

Plotting Worst Day Es/N0 Time Series for Year

Plotting Es/N0 against Elevation Angle for Maximum Availability

Plotting Monthly Total Outages Mean and Standard Deviation

Plotting Accumulated Outage Time (in minutes) per ear for CCM

Plotting Elevation Angle per Samples foreach Year

Plotting Completely Lost Passes (if any)

Plotting Total Attenuation against Elevation Angle

Plotting Total Outages for All Years and All Months

Plotting Statistics for Worst Year in terms of Outages

Plotting Contiguous Outage Durations for each Month

Plotting Contiguous Outage Durations for Selected Years

Plotting Decomposition of Total OutagesWriting Output of Atmospheric Attenuation Computation...

Atmospheric Attenuation Computed Successfully!

Writing Link Budget Output File...

Link Budget Computed Successfully!

Best MODCOD Combinations File was not provided or does not exist.

Computing Link Outages without optimization.

Writing Link Outages Output File

Link Outages Computed Successfully!

WARNING CFDP Class to be computed not specified in Configuration File...

Computing both CFDP Classes (1 and 2).

WARNING Data Rate not specified in Configuration File...

Data Rate Default Value is 1600.0

WARNING - No Timeout as been defined for CFDP Class 2 computation

A CSV File will be generated with a summary of the CFDP Statistics Computations

Computing CFDP Class 1 and 2 Statistics

```
Computing CFDP Class 1 and 2 Statistics

Computing CFDP Class 1 and 2 Statistics

CFDP Statistics Computed Successfully!


Plotting Contiguous Outages Durations per Hour

Plotting Time Percentage of Contact in Outage

Plotting Worst Day Es/N0 Time Series for Year

**ERROR**  Optimization File provided, does not exist, thus some data cannot be plotted

Plotting Es/N0 against Elevation Angle for Maximum Availability

**ERROR** - Optimization File provided, does not exist, thus some data cannot be plotted

Plotting Monthly Total Outages Mean and Standard Deviation

Plotting Accumulated Outage Time (in minutes) per ear for CCM

**ERROR** - Optimization File provided, does not exist, thus some data cannot be plotted

Plotting Elevation Angle per Samples foreach Year

Plotting Completely Lost Passes (if any)

Plotting Total Attenuation against Elevation Angle

Plotting Total Outages for All Years and All Months

Plotting Statistics for Worst Year in terms of Outages

Plotting Contiguous Outage Durations for selected years

Plotting Decomposition of Total Outages
```

The expected directories and files structure after running all modules is the following:

```
outputs/orchestrator/Non-Opt
├── CO2M Svalsat CFDP1 2002 20240603234942
│   ├── link availability 97 5
│   ├── link availability 99 0
│   └── link availability 99 9
├── CO2M Svalsat CFDP1 2004 20240603234942
│   ├── link availability 97 5
│   ├── link availability 99 0
│   └── link availability 99 9
├── CO2M Svalsat CFDP1 2005 20240603234942
│   ├── link availability 97 5
│   ├── link availability 99 0
│   └── link availability 99 9
├── CO2M Svalsat CFDP2 2002 20240603234942
│   ├── link availability 97 5
│   ├── link availability 99 0
│   └── link availability 99 9
```

```
├── CO2M_Svalsat_CFDP2_2004_20240603234942
│   ├── link_availability_97_5
│   ├── link_availability_99_0
│   └── link_availability_99_9
├── CO2M_Svalsat_CFDP2_2005_20240603234942
│   ├── link_availability_97_5
│   ├── link_availability_99_0
│   └── link_availability_99_9
├── CO2M_Svalsat_GlobalStats_20240603234942
│   ├── Att_vs_theta_svalsat_for_multiple_avail.png
│   ├── EsNo_vs_theta_svalsat_for_avail_97.50.png
│   ├── EsNo_vs_theta_svalsat_for_avail_99.00.png
│   ├── EsNo_vs_theta_svalsat_for_avail_99.90.png
│   ├── Svalsat_average_monthly_outage_over_3_years.png
│   ├── Svalsat_best_data_volume.png
│   ├── Svalsat_contiguous_outages_duration_for_month_8.png
│   ├── Svalsat_contiguous_outages_duration_for_year_2002.png
│   ├── Svalsat_contiguous_outages_duration_for_year_2004.png
│   ├── Svalsat_contiguous_outages_duration_for_year_2005.png
│   ├── Svalsat_contiguous_outages_duration.png
│   ├── Svalsat_contiguous_outages_hour_day_for_month_8.png
│   ├── Svalsat_cumulated_yearly_outage_time.png
│   ├── Svalsat_data_volume_best.png
│   ├── Svalsat_hour_outages_year.png
│   ├── Svalsat_lost_passes.png
│   ├── Svalsat_outage_elev_angle_2002.png
│   ├── Svalsat_outage_elev_angle_2004.png
│   ├── Svalsat_outage_elev_angle_2005.png
│   ├── Svalsat_standard_deviation_mean_contact_time_over_ten_years.png
│   ├── Svalsat_Time_percentage_the_contact_in_outage.png
│   ├── Svalsat_total_monthly_outage.png
│   ├── Svalsat_total_yearly_outage_percentage.png
│   ├── Svalsat_worst_day_EsN0_time_series_for_year_2002.png
│   ├── Svalsat_worst_day_EsN0_time_series_for_year_2004.png
│   └── Svalsat_worst_day_EsN0_time_series_for_year_2005.png
├── CO2M_Svalsat_AtmosphericAtt_20240603234942.xml
├── CO2M_Svalsat_LinkBudget_20240603234942.xml
├── CO2M_Svalsat_LinkOutages_20240603234942.xml
└── CO2M_Svalsat_outage_time_series_20240603234942.nc─outputs/orchestrator/Non-Opt
```

```
├── CO2M_Svalsat_CFDP1_2002_20240514113133
│   ├── link_availability_97_5
│   ├── link_availability_99_0
│   └── link_availability_99_9
├── CO2M_Svalsat_CFDP2_2002_20240514113133
│   ├── link_availability_97_5
│   ├── link_availability_99_0
│   └── link_availability_99_9
├── CO2M_Svalsat_GlobalStats_20240514113133
│   ├── Att_vs_theta_svalsat_for_multiple_avail.png
│   ├── Svalsat_average_monthly_outage_over_1_years.png
│   ├── Svalsat_contiguous_outages_duration.png
│   ├── Svalsat_cumulated_yearly_outage_time.png
│   ├── Svalsat_hour_outages_year.png
│   ├── Svalsat_lost_passes.png
│   ├── Svalsat_outage_elev_angle__2002.png
│   ├── Svalsat_standard_deviation_mean_contact_time_over_ten_years.png
│   ├── Svalsat_Time_percentage_the_contact_in_outage.png
│   ├── Svalsat_total_monthly_outage.png
│   └── Svalsat_total_yearly_outage_percentage.png
├── CO2M_Svalsat_AtmosphericAtt_20240514113133.xml
├── CO2M_Svalsat_LinkBudget_20240514113133.xml
├── CO2M_Svalsat_LinkOutages_20240514113133.xml
└── CO2M_Svalsat_outage_time_series_20240514113133.nc
```