LHP Module enhancement Executive Summary

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CHANGE RECORDS

ISS.	Rev.	DATE	CHANGES	AUTHORS
1	0	January 2018	Initial version	L. Zurawski

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1. APPLICABLE DOCUMENTS

Ref.	Document name	Document Reference	Iss.	Date
AD01	ESA-LHP module contract	4000112941	1	Sept 2015
AD02	STATEMENT OF WORK ESA Express Procurement EXPRO « Enhancement of Loop Heat Pipe (LHP) Modelling Tool"	ESA – TEC-MTV/2014/3774/ln/JE	1	August 2014
AD03	DETAILED PROPOSAL In answer to: ESA RFP No. IPL-PTM/PA/fg/500.2014 "Enhancement of Loop Heat Pipe (LHP) Modelling Tool"	TSPES81.PC.PT.730405.14		Nov 2014

2. REFERENCE DOCUMENTS

Ref.	Document name	Document Ref.	Iss.	Date

3. ABREVIATIONS AND DEFINITIONS

GSTP	General Support Technology Programme
GUI	Graphical User Interface
LHP	Loop heat pipe
NCG	Non-condensable gas
S/C	Spacecraft
S/L	Satellite

4. INTRODUCTION

LHPs are more and more used in space for current & future applications, due to their performances (in terms of weight, design flexibility, thermal transport capacity and accommodation flexibility).

The LHP Module software enables to model Loop Heat Pipes (LHP) for system level thermal analyses. The previous version of the Module (v2), developed in the frame of a R&T CNES activity is fully operational and has been used on a number of programs. However, it does not cover some new growing needs consisting:

- complex architectures as multi-condensers or multi-branches configurations
- New advanced components enabling to better control the loop performances (regulation valves, capillary blockers …)
- Gravity effect to better understand and correlate ground tests

Moreover, a customer survey highlighted the need to improve the Module in terms of performances and ease of use. The module has also to be compatible with the main thermal solvers used by the European space community: Esatan, Thermisol and E-Therm.

The purpose of the GSTP "LHP Module enhancement" is then to provide to the European Space community with a new version covering these needs.

This document is the Executive Summary and concisely synthetises the findings of the program, run through collaboration between Airbus (Space Systems), Thales-Alenia Space and CNES/ESA agencies.

5. IMPROVEMENTS VERSUS PREVIOUS VERSION

This section gives an overview of the improvements brought to the LHP Module v3 in terms of functionalities, performances and ease of use.

5.1 New capabilities

With LHP Module v3, the user has the possibility to:

- define either multi-branches or multi-condensers (with multi-branches) configuration up to 2 levels of parallel branches, which covers most of the current & future needs in terms of complex architectures
- add either 2 or 3 ways valve in order to regulate the flow:
  - according to the fluid temperature for a 2 ways valve
  - by splitting the flow between reservoir and condenser for a 3 ways valve
- model the effect of a capillary blocker (also called isolator) that blocks the vapour that could remain at the condener outlet and perturb LHP operation
- model the effect of NCG (Non Condensable Gas) which modify the pressure in the LHP and affect thermal performances

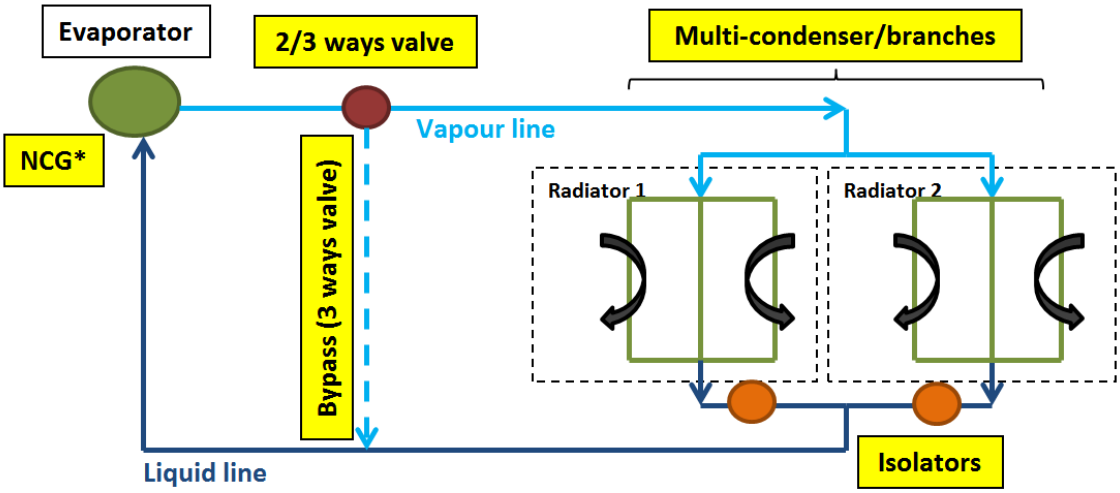

Figure 6-1. Overview of LHP Module v3 new capabilities

5.2 Time step management

For transient solutions, the modelling of LHP requires to use a low time-step (typically 1 second), so as to ensure convergence.

On the opposite, a typical System model requires far higher time step (typ. 1 minute) to get acceptable cpu time.

Consequently, to keep acceptable time step at System level, an additional convergence loop at cell level has been introduced to get consistent values for tubing temperature, fluid state at cell outlet, before processing following cell, as illustrated in the next figure.

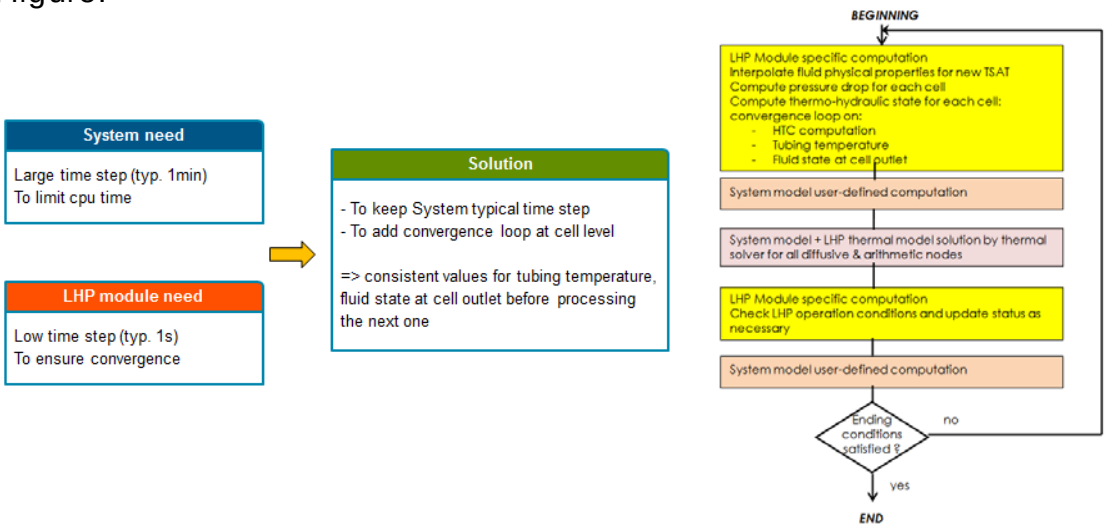

Figure 6-2. Time step management

5.3 General improvements

5.3.1 Compatibility with thermal solvers

The LHP Module v3 is fully compatible with the following thermal solvers, which cover most of the European Space community needs:

- Esatan (v2016 and latter)
- Thermisol (v4.5.3b and latter)
- E-Therm (v2.3 and latter)

5.3.2 Simplification of input and output files

For the previous version of the Module, lot of input files were to be defined and the output file contained all the needed information but readability was lacking.

For the new version, the input files number has been limited to 3:

- Evaporator hardware definition
- Piping definition
- Fluid properties

In particular, the piping definition was highly simplified. The sequential definition, from evaporator to reservoir is intuitive (cells features, split, valves or capillary blocker addition ...).

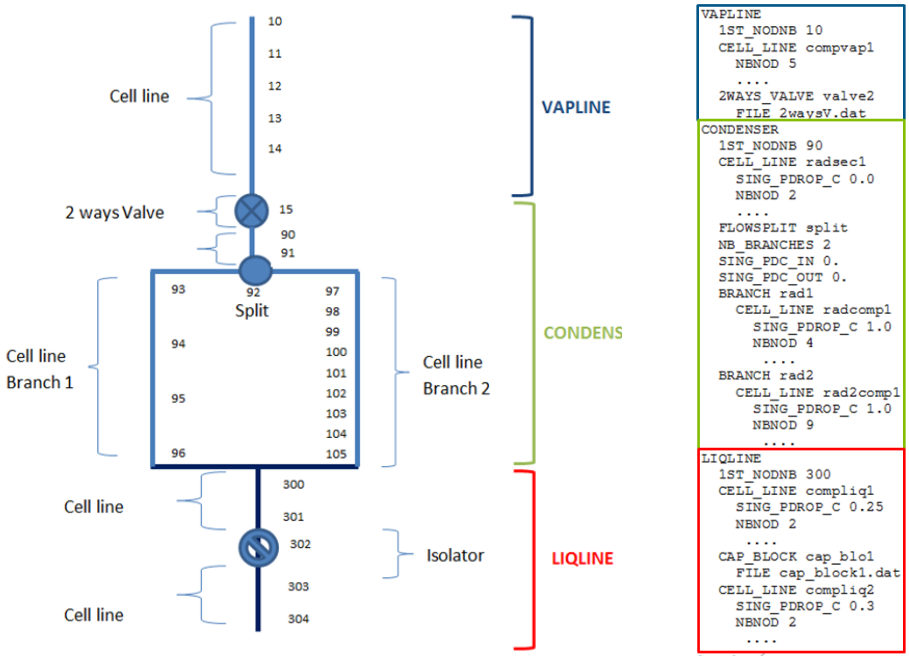

Figure 6-3. Example of piping definition

The output file was split into 3 different files for better readibility:

- LHP(s) data read status, warnings and errors
- LHP(s) thermal, hydraulic characteristics and flux budget
- LHP(s) convergence parameters

6. DELIVERY TO EUROPEAN SPACE COMMUNITY

6.1 Black boxes

The LHP Module v3 is delivered in the form of Black Boxes. These Black Boxes are available for both Esatan and Thermisol solvers.

Black Box	Folder	Content	Description
Thermisol	DEV	LHPv3_0_1_bbox_solv.DCK	LHP module Black Box Thermisol version
		Thsol_Lib	Fortran libraries
	TEST	TSTSPLIT	Split acceptance test
Esatan	DEV	LHPv3_0_1_bbox_esat.DCK	LHP module Black Box Esatan version
		Esat_Lib	Fortran libraries
	TEST	TSTSPLIT	Split acceptance test

Figure 7-1. Black Boxes content

The acceptance test enables the user to ensure that the Module is properly installed.

The requested configuration is defined in the next table.

Solver	Library name	Platform	Encoding	Compiler
Thermisol	Liblhp301-gfortran-64LNX.a	Linux	64 bit	gfortran
	Liblhp301-g77WIN.a	Windows	32 bit	g77
Esatan	Liblhp301-gfortran-64LNX.a	Linux	64 bit	gfortran
	Liblhp301-gfortran-64WIN.a	Windows	64 bit	gfortran

Figure 7-2. Black Boxes requested configuration

Note: these configurations are supposed to cover most of the needs. If needed, addition libraries may be delivered.

6.2 Documents

The delivery includes the following documents:

- Software Design Document
- User Manual (including Installation Manual)

7. WAY FORWARD

7.1 Gravity effect

The gravity effect implementation was supposed to be based on tests performed early 2017 in the frame of CNES/Airbus R&D program. However, these tests highlighted some unexpected results and additional tests have to be performed (planning not yet defined).
So the gravity effect detailed implementation is postponed for a future ITT.

7.2 Transient phenomena

There is a growing need to better model the transient phenomena (start-up & restart conditions, initiation phase, oscillating modes …). Airbus started some discussions with LHP manufacturer and really interesting improvements suggestions were highlighted. So in the frame of a future ITT, cooperation with LHP manufacturer with strong heritage on this topic would be fruitful.

7.3 Graphical user interface

GUI (Graphical User Interface) tool providing a 2D visualization of the loop:

- Pre-processing: to check piping definition
- Post-processing: to visualize computation results (cells temperature, condensation front location …), to build Clapeyron diagram

8. CONCLUSION

The new version of the LHP Module developed in the frame of GSTP "Enhancement of LHP modelling tool" enables to cover most of the new identified needs:

- complex architecture (multi-branches, multi-condensers configurations)
- components enabling to better control the loop performances (2 ways and 3 ways valves, capillary blocker)
- NCG (Non-Condensable-Gas) effects

Moreover, the new version is more in line with System analysis level requirements enabling to define higher time step thanks to the implementation of an internal convergence loop at cell level.

The ease of use was also improved with simplification of both input and output files and a more intuitive piping definition. The Module is compatible with Thermisol, Esatan and E-Therm solvers.

However, there is still a lot of work to do to improve LHP Module in terms of representativeness (gravity effect, transient phenomena) and ease of use (add of a GUI tool for both pre and post-processing).