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MDS

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Thermal and fluid dynamic analysis of the air cooling/conditioning on board of MDS (Mice Drawer System) facility

CBA Centro Biotecnologie Avanzate
ABC Advanced Biotechnology Center

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MICE DRAWER SYSTEM

- MDS main features:
  - Facility dedicated to experiment on mice strains
  - able to host till 8 grouped mice or 6 individually
  - able to delivery dedicated quantity of food and liquids
  - able to supply air flow for mice well being
  - able to manage mice waste
  - able to sustain experiment phase for 100 days

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MICE DRAWER SYSTEM

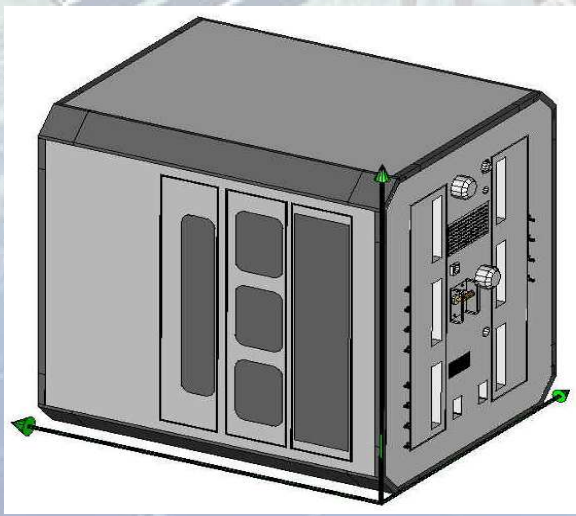
- MDS main features:
  - Double Middeck Locker replacement payload
  - able to interface Middeck during on orbit transportation
  - able to interface Express rack in US lab on orbit
  - able to interface crew for maintenance
  - able to minimise crew time w.r.t. animal needs

M D S

- Mice Chamber (MC)
- Air Conditioning Subsystem (ACS)
- Food Delivery Subsystem (FDS)
- Illumination Subsystem (ILS)
- Liquid Handling Subsystem (LHS)
- Observation Subsystem (OSS)
- Payload Control Unit (PCU)
- External Container

EXTERNAL CONTAINER

- The principal structural part of MDS is the External Container that supports all the subsystems and it's packaged with Pyrell Foam and inserted into DMDL



•Nodalization of EC and DMDL box

•GL conductors with Pyrell foam

•The model is defined into elemuser.dat
•and called by main programm

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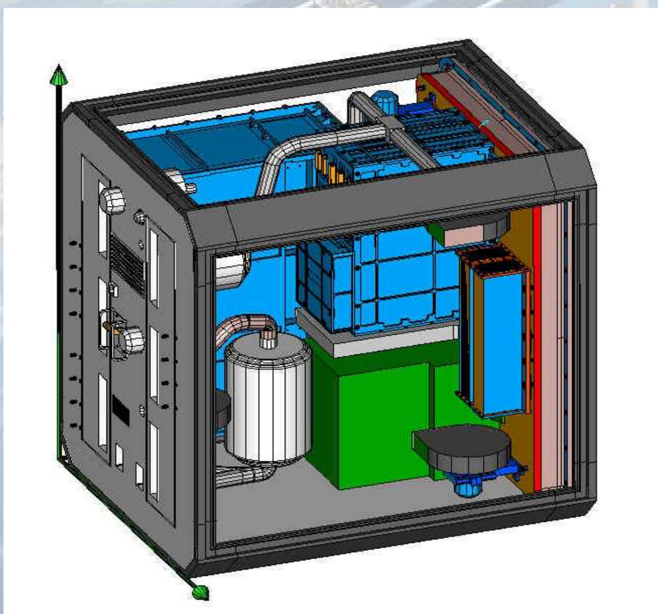
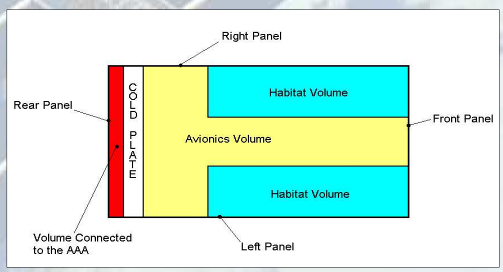
VIEW INSIDE EXTERNAL CONTAINER



- Three separated zones are present inside MDS:
  - Habitat volume
  - Avionics volume with electronic box, LHS, etc.
  - The zone connected to the AAA.



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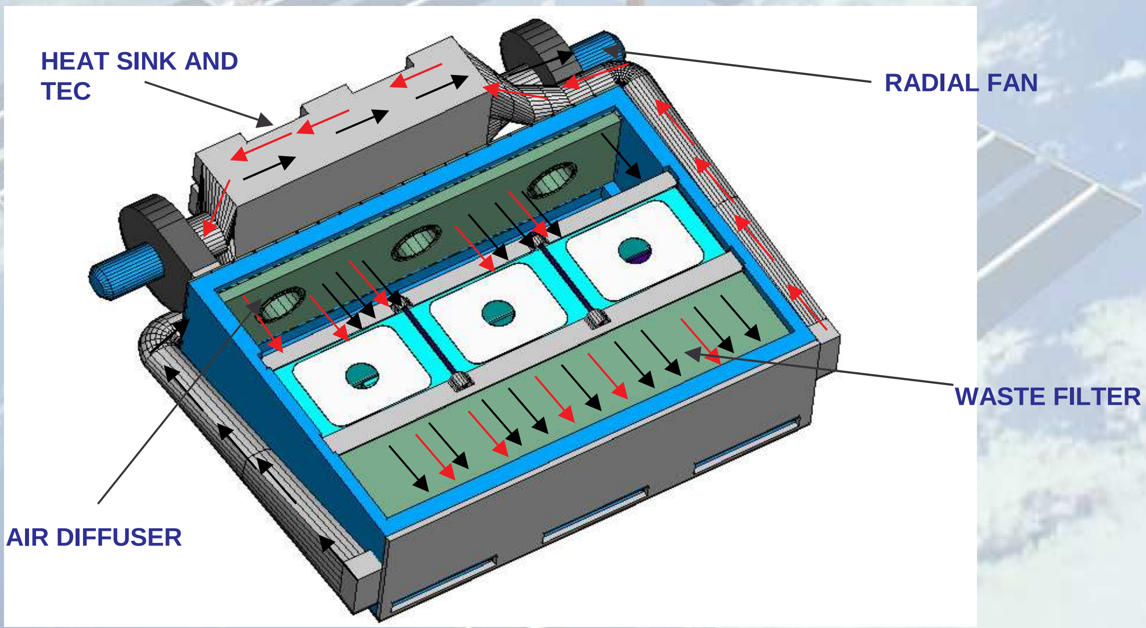
HABITAT VOLUME :Life Air Support Loop



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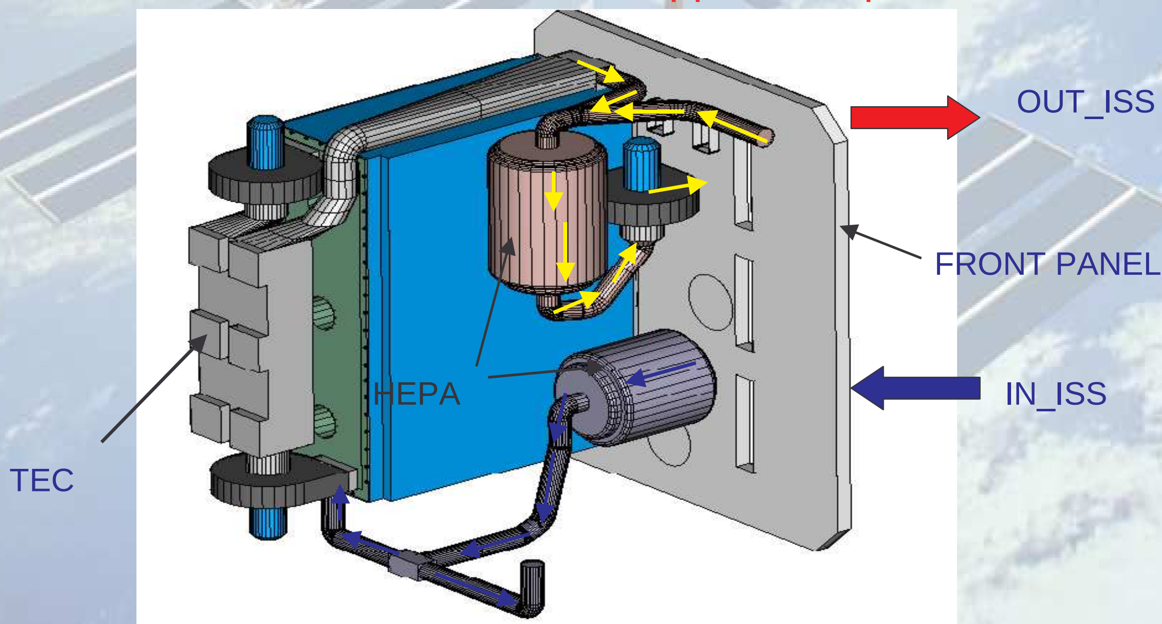
HABITAT VOLUME: Life Air Support Loop P/L-ISS



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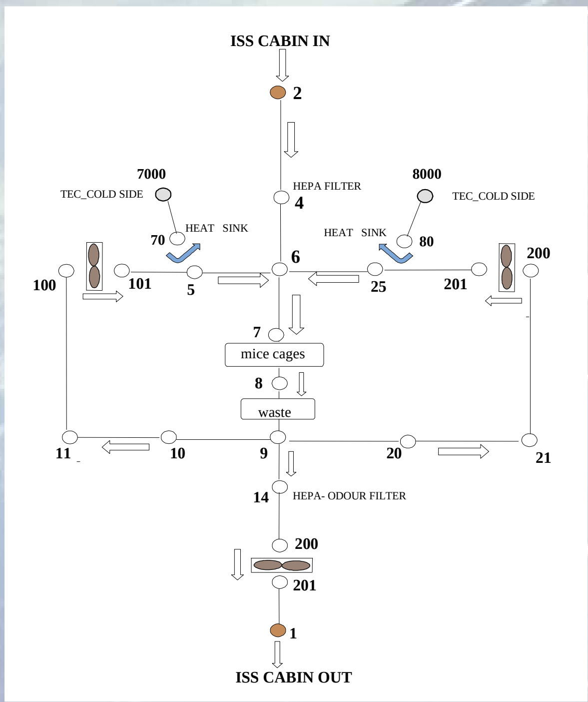
LIFE AIR SUPPORT NETWORK



Elemuser contains the fluid network to simulate the life air support loop in each habitat.
- Fan is defined using mass source/sink
- The pressure drop into the waste filter and pre-filter is defined using GP link
- Heat exchanger is connected to air loop thanks a GL =eff*S*hc
- Tec cold side is connected to HX by linear conductance GL with thermal grease characteristics and assembly by torlon screws
- Nodes:2-1 represents the boundary (Type R) of ISS Cabin conditions.

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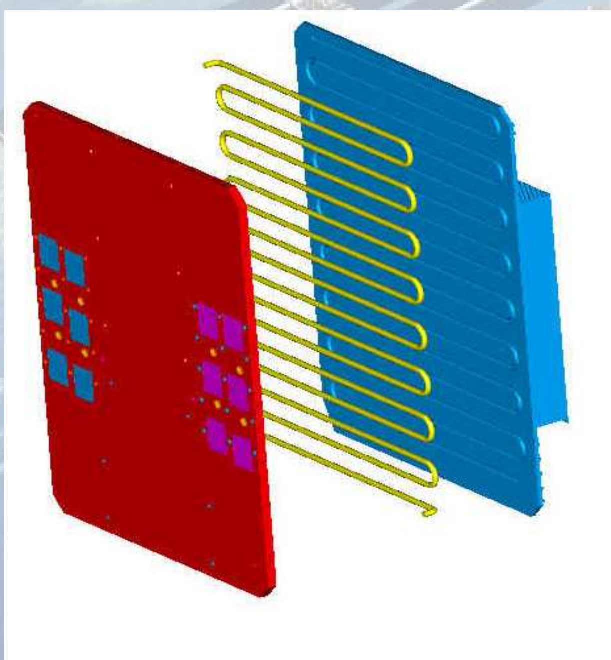
• HYBRID COLD PLATE



Cold Plate model:

- Coldplate of FHTS element
- Definition of parameters of discretization and all inputs about material property and flowrate.
- Linear conductive link between heat load and plate thermal nodes
- The cold plate is fixed by screws to the rear EC, but there is a thermal decoupling by insulating material

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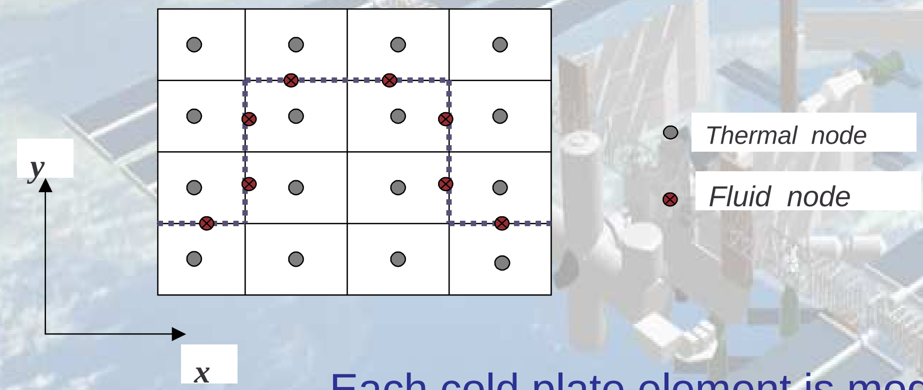
COLD PLATE ELEMENT



Each cold plate element is modelled as 2D plate containing a U-shaped fluid tube.

Capability to specify discrete heat source corresponding to thermal nodal within the plate

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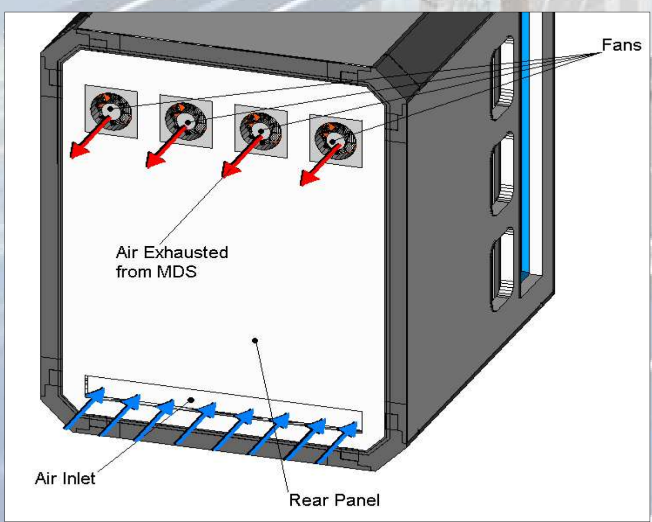
VOLUME CONNECTED TO THE AAA

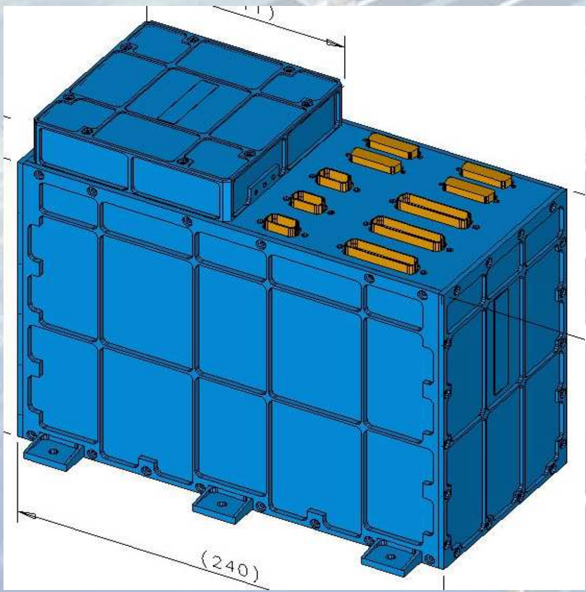
- In this volume there are the cooling ribs and four axial fans.



Heat sink is modelled using a conductive and convective GL and M for flowrate through the fins.

The Avionics fans suck up the air from the Avionics Bay

• PAYLOAD CONTROL UNIT



•Semplified model for each board (1 node)
•Link between the board and box using experimental value of GL conductors
•Link between PCU-Cold Plate nodes

<u>output</u>

•<u>MaxT for all boards</u>
•<u>Sides' temperature of the box</u>

•Thermal Design

•Survival operational mode

- Life Air Support Loop

-Avioncs Air Loop (supplied by Avionics Air Assembly)

•Experimental operational mode

- Life Air Support Loop

-Moderate temperature water Loop (supplied by ISS)

Survival operational mode

•All subsystem are turned off, except:

-4 radial fans for the air recirculation in mice volume

-radial fan for the air blowing to the ISS

-12 TEC

-ILS (electrical power reduced to 50%)

•Cooling system is AAA

Experimental operational mode

•All subsystem are turned on

•Cooling system is MTL

THERMAL ANALYSIS

THERMAL REQUIREMENTS

The facility has to withstand the following thermal requirements:

- **The maximum return temperature from the payload to the MTL shall be less than 48.9°C**
- **The maximum return temperature from the payload to the AAA shall be less than 48.9°C**
- **The pressure drop between the inlet and outlet QDs of payload utilizing MTL shall be 19.3 ± 1.03 KPa at the desiderate flow rate**
- **The MDS habitat air temperature shall be kept between 25 - 30°C**

THERMAL MATHEMATICAL MODEL

BOUNDARY CONDITION

Survival mode:

AAA flow rate	750 l/min
AAA pressure	101 KPa
AAA temperature (*worst case)*	29.4°C
ISS Cabin Pressure	104.8 KPa
ISS Cabin temperature	28°C
Air recirculation into mice chambers volume	480 l/min
Air blowing to the ISS	17 l/min
MDL Temperature	35 °C

Experimental mode:

Water coolant flow rate	100 lbm/hr
Water pressure	834 KPa
Water temperature (*worst case)*	23°C
ISS Cabin Pressure	104.8 KPa
ISS Cabin temperature	28°C
Air recirculation into mice chambers volume	480 l/min
Air blowing to the ISS	17 l/min
MDL Temperature	40 °C

Thermal budget

Survival operational mode

- T mice =29°C - TMDL=35°C

HEAT LOAD HABITAT +TEC	63.6 W	+ 15% → 73 W
PCU + ILB + ½ RADIAL FAN	39 W	+ 15% → 45 W
TOTAL HEAT LOAD dissipated into the cold plate	-	118 W

AAA Fans (their contribut is on the AA in output)	**12 W**	**15% → 13.8**
½ Radial Fan + LED (Front panel)	**6.4 W**	**+15% → 7.4**
TOTAL HEAT LOAD dissipated out of the cold plate	**-**	**21.2 W**

THERMAL BUDGET = 139 W

Experimental operational mode

- T mice =25°C - TMDL=40°C

HABITAT HEAT LOAD AND TEC	118 W
PCU	43 W
OSS-LHS	7 W
TOTAL HEAT LOAD Dissipated into the CP	166 W

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RADIAL FAN P/L to ISS CABIN	5 W
LED ON THE FRONT PANEL	1 W
TOTAL HEAT LOAD Dissipated out of the cold plate	6 W

THERMAL BUDGET = 172 W

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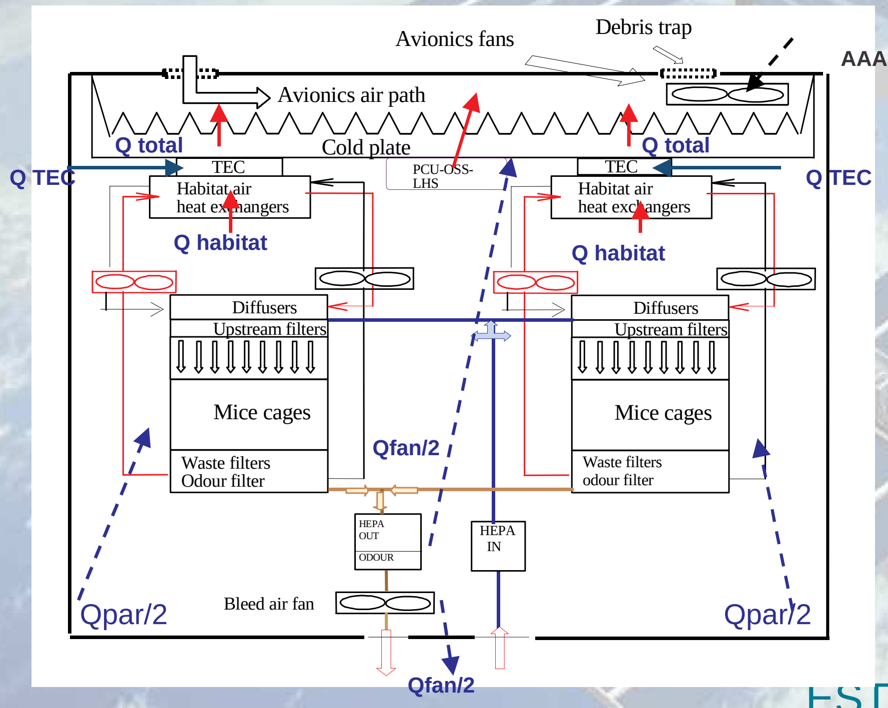
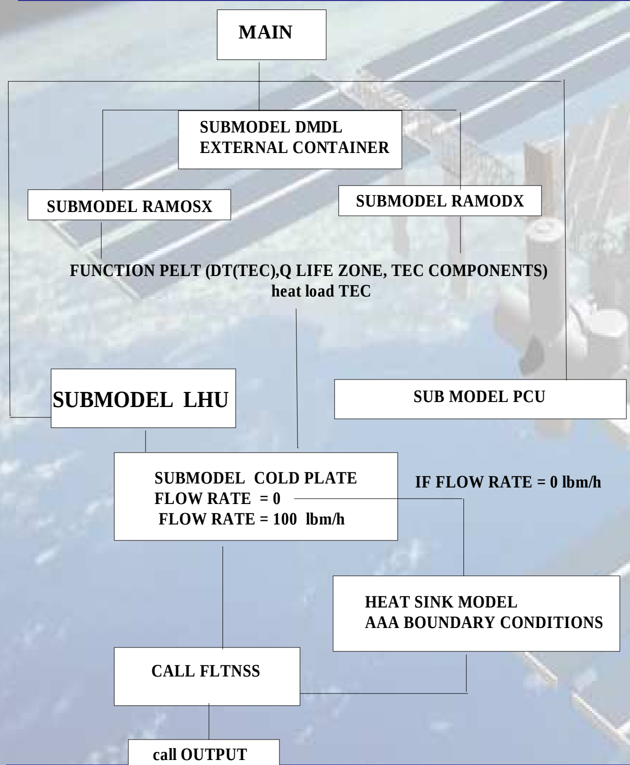
HEAT FLUX PATH



•FLOW CHART



The main sub_models are:

- Sub_model EC/DMDL
- Sub_model ramosx
- Sub_model ramodx
- Sub_model Coldplate
- Sub_model PCU
- Sub_model LHS
- Sub_model OSS Module

Parameters and function for simulation

- Main contains the links between all subsystems in elemuser.dat and calls Elemsys.dat (coldplate) and solver routine
- Elemuser.dat contains the subsystem submodel (PCU,LHS,OSS,HABITAT,EC,DMDL)
- GP allows to define the concentrate pressure drop in the filter ,pipes and QDs
- Mass source/sink define the fans
- Peltier function simulates the real TECs behaviour and power

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RESULTS

•SURVIVAL

LOCATION	NODES	T [°C]	P [Pa]
AAA_OUT	600	37.5	101288
Mice chambers	7	29	104691
Fan_Out_ISS Cabin	201	44.3	104800
PCU	1021-1044… 6021-6044	39	-

RESULTS

•EXPERIMENTAL

LOCATION	NODES	T [°C]	P [Pa]
MTL_OUT	800100	26.5	821487
Mice chambers	7	25	104692
Fan_Out_ISS Cabin	201	44.3	104800
PCU $Plate1	1021-1044... 6021-6044	29	-
LHS $Plate2	1018-1045	27	-

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CONCLUSIONS

- Flexibility of the model management
- Capability to simulate the mission profile
- Easiness to change parameters of main thermal components (Fan choice,Hx efficiency,cold plate performance)
- Advanced simulation of TEC behaviour

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