

RIT MicroPropulsion System on Lisa Pathfinder

IEPC-2011-325

*Presented at the 32nd International Electric Propulsion Conference,
Wiesbaden • Germany
September 11 – 15, 2011*

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ABSTRACT: A feasibility study of implementing a MicroPropulsion Subsystem (MPS) based on the RIT technology in place of the FEEP for the LISA Pathfinder mission was performed. The mission imposes stringent requirements on the MPS thrusters in terms of thrust range and dynamics, thrust accuracy, thrust noise and stability. In addition, the mission application brings significant constraints for integration on a spacecraft that is reaching the end of its development, not only in terms of mass and power, but also in terms of mechanical and electrical integration without impacting what has already been build and verified at system level.

Previous tests performed on a miniRIT thruster operating at higher thrust levels showed the capability to comply with those requirements and constraints. A number of RIT thrusters were designed, built and tested to verify compliance to the major LISA Pathfinder MPS specifications. The system implications of using a RIT MPS have been studied. Restrictions on power and mass budgets, use of existing interfaces had to be taken into account. Existing FEEP MPS equipment and units, e.g. PCUs and Neutralizers, were re-used as far as possible. Different RIT MPS architectures were considered. Finally, to minimise the impact on the already built platform, the RIT MPS was designed as a form fit replacement of the Slit FEEP MPS.

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I. Introduction

LISA Pathfinder is an experiment to demonstrate Einstein's geodesic motion in space more than two orders of magnitude better than any past, present, or planned experiment, except for LISA. The MicroPropulsion system is a fundamental Subsystem to enable the LISA mission. Together with the DFACS and the inertial sensor it is the key technology to be tested on LISA Pathfinder. This paper presents the results of the feasibility study of implementing a MicroPropulsion Subsystem (MPS) based on the miniRIT technology in place of the FEEP MPS on LISA Pathfinder. The objectives of this study were to preliminary definition of the design and characteristics of such subsystem, addressing budgets, performances and risks. The subsystem has been designed with the maximum reuse of existing technology and units, while at the same time reducing the impact to the already assembled platform. An attempt has been made to design the miniRIT MPS as a form and fit replacement of the slit/needle FEEP for which the platform is designed for.

II. The LISA Pathfinder Spacecraft and the MPS design drivers and system constraints

The LISA Pathfinder spacecraft comprises two modules, namely:

- The Science Spacecraft (SCM)
- The Propulsion Module (PRM).

The SCM contains the two main sensor packages, the LTP (LISA Technology Package) and DRS (Disturbance Reduction System, provided by NASA), the MicroPropulsion Subsystem and the drag free control system. The SCM also accommodates the spacecraft equipment required to provide support functions to the payloads over the mission lifetime. The inertial sensor core assemblies are mounted on a dedicated compartment within the central cylinder. The payload electronics and spacecraft equipments are accommodated on shear panels as far away as possible from the sensors to minimize gravitational, thermal and magnetic disturbance. The thrusters' assemblies are arranged symmetrically on the outer panels to provide full control in all axes. The Colloid thrusters (part of the DRS) are mounted on opposing outer panels.

The target orbit is at the Earth-Sun L1 Lagrange point. The PRM orbital transfer module takes care of the transfer from the launcher insertion orbit up to L1. This orbit provides a benign gravitational environment at Earth ranges of 1.2 to 1.8 million km, with stable solar illumination and freedom from eclipses. The spacecraft can stay in such an orbit for the operational lifetime of 11 months with the application of periodic station keeping manoeuvres of 1-2 m/s per year using the Micro-Propulsion thrusters. The PRM propulsion module separates from the science spacecraft module prior to drag free operations to prevent disturbances that would be generated by the residual propellants of the chemical propulsion system acting on the inertial sensors.

A set of design guidelines were developed early during the RIT MPS design assessment:

- The design shall be based on existing proven technology
- The design shall minimize the need for modifications to the existing spacecraft bus
- Change of technology from FEEP to RIT shall minimize the need to repeat already completed system level verification
- Integration shall not require disassembly of other than directly affected hardware
- The system shall not introduce new hazards impacting spacecraft launch processing.
- Thruster cluster layout shall be limited to re-use of existing interfaces, thereby essentially limiting to three self standing units
- Moving parts shall be avoided during operation
- The system shall be compatible with the available spacecraft resources, and provide all required functionality
- Existing hardware shall be re-used, if beneficial
- The design shall have no credible single point failure modes



Figure 1: LPF spacecraft during acoustic test at ESTEC

III. The RIT MPS Subsystem

The RIT Micro-Propulsion Subsystem (MPS) is based on the RIT thruster technology. Radio-frequency Ion Thrusters (RITs) generate thrust by the electrostatic acceleration of xenon ions. Since the middle of the 60th of the last century, RIT Thrusters have been designed, built and qualified by Astrium Lampoldshausen (D) and University of Giessen (D). These thrusters cover the thrust range from 10mN to 250mN. RIT10 has been the first Western European ion thruster operated in space on EURECA (European Retrievable Carrier) mission. Since 2003, RIT-10 is flying in space onboard ARTEMIS satellite.

The development of the miniRIT thruster, initiated in 2005, bases on the heritage in design, development, test and space operation of RIT10. Since 2005 several miniRIT breadboard models have been built and tested to respond to the need of micro-propulsion systems in the mN regime.

The RIT Micro-Propulsion Subsystem design for Lisa Pathfinder consists of three main elements called Micro Propulsion Assembly (MPA), each one consisting of one RIT Cluster Assembly (RCA), one Power Control Unit (PCU), one RFG unit with four channels and one Neutraliser Assembly (NA) as shown in Figure 2.

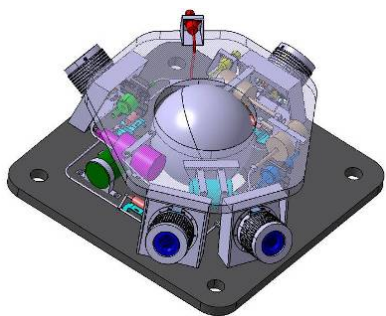


Figure 3: RCA

RFG for ionisation of the propellant and two voltages lines for the acceleration of the ionised propellant in the thruster's grid system. Neutral xenon gas is injected into the thruster' ionisation unit via an integrated insulator and gas distributor. The ionisation occurs in a vessel made by an insulating material (discharge chamber) and surrounded by the induction coil (RF Antenna) that is part of the resonance circuit of a radio frequency generator (RFG). The induced electric eddy-field accelerates electrons and generates a self-sustaining, electrodeless gas-discharge. From this plasma the ions are extracted, focused, and accelerated by a two-grid system ultimately generating thrust.

To feed propellant into each thruster, a Xenon Storage & Feed System (XSFS) is implemented inside each RCA. The main task of the XSFS is to store in one litre high pressure tank and distribute the xenon from the tank to each thruster at constant flow rate. A schematic of the XSFS is depicted in Figure 5. High and low pressure sections have been separated to facilitate separate integration and test, and separate thermal control. Use of COTS components is envisaged; the only exception to be the Flow Restrictor (FR). The mini-RIT operates at a constant flow rate that is provided by the flow restrictor (FR). Solutions with a variable flow rate (using proportional valves) would allow wider range of thrust but would require moving part in the flow regulation, albeit with very small mass. The present subsystem design has a single FR

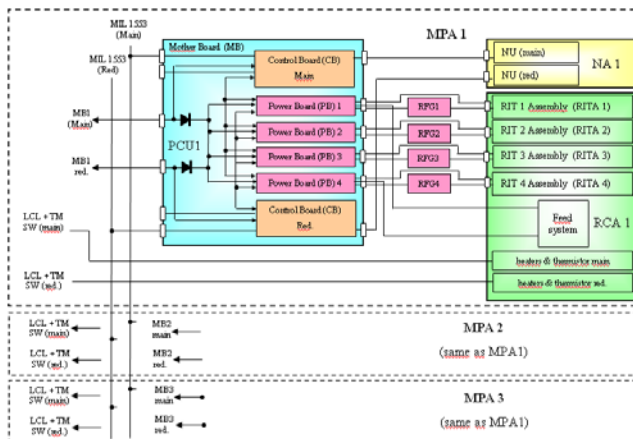


Figure 2: LPF RIT MPS block diagram

Each RCA, depicted in Figure 3, has been designed as a self-contained unit hosting four RIT-Thrusters and the Xenon Storage and Feed System, mounted on a support structure with any necessary interfaces and support brackets (mechanical, thermal and electrical). The four thrusters are devoted to provide thrust to the required vector directions and they are commanded individually.

The MiniRIT generates thrust by the electrostatic acceleration of ionized xenon particles. For its operation the thruster requires propellant (xenon) and electric power. The RIT thruster needs two voltage lines to feed the

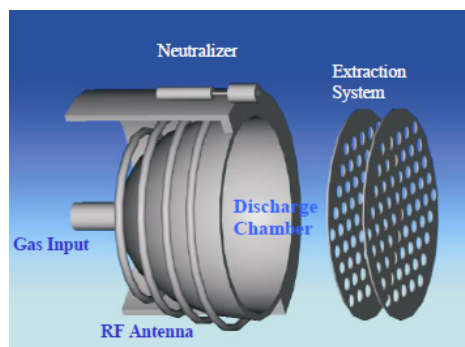


Figure 4: Functional principle of RIT

for each thruster, which allows for one fixed flow rate (2.5 $\mu\text{g/s}$).

The miniRIT Power Control Unit consists of a self-contained electronic unit mounted on a support structure with any necessary interfaces and support bracket (mechanical, thermal and electrical). The PCU interfaces the spacecraft (Power and TC/TM tasks) and provides power and control to four independent thrusters in order for them to deliver thrust at the commanded level. In addition, each PCU provides power and control to two neutralizers, four RFGs, to the xenon storage and feed system and xenon thermal control. In principle no other connections are necessary from the spacecraft avionics, with the exception of the survival heaters' lines. The radio-frequency generator (RFG) is the driver for the ionization process inside the RIT thruster and the main control element of the thrust. The RFGs are packaged inside 3 modules each placed below each PCU. Each RFG module hosts 4 RFGs. Each RFG drives a single thruster. Reusability of the LPF FEED PCU has been discussed and trade-off [1]. As conclusion of the trade off and assessment involving the LPF PCU design authority, reusability of the current FEED PCU has been confirmed. The changes needed in each type of board are:

- Power Boards shall be redesigned and built as reuse of FEED boards is not feasible because all the functional blocks need to be updated. It is worth recalling that with the smaller HV section required by mini-RIT device (e.g. positive voltage reduced from 12 KV to 2 KV), about 20-25% of the PCB area of the Power Board remain spare and available for further modifications or possible RFG allocation.
- Control Boards should require smaller changes, consequently can be reusable, with wired modifications. However, due to the request for additional telemetries (e.g. thermistors, pressure sensors) and relevant circuitry, additional heater control, it is anticipated that partial redesign and consequently rebuilding could be necessary if bringing in potential saving in the power consumption. It is worth recalling that 10% of the PCB area could be free and available for further modification in case the Control Boards need to be rebuilt
- Mother Boards should require small modification and consequently can be considered reusable. It is worth recalling that since these boards are less expensive than control boards (as well faster to be manufactured), possible redesign and rebuild of these boards remain in any case not an issue. This option can be followed if detailed design will require more complex cross-strapping functions among modules.

The LISA pathfinder Neutralizer Assembly (NA), originally designed for the FEED MPS, consists of a self-contained unit of two Neutralizer unit mounted on a support structure. The neutralizer is necessary to nullify the spacecraft charge build-up due to the ion thruster operation. The neutralization function is implemented by means of cold redundant hardware. The neutralizer

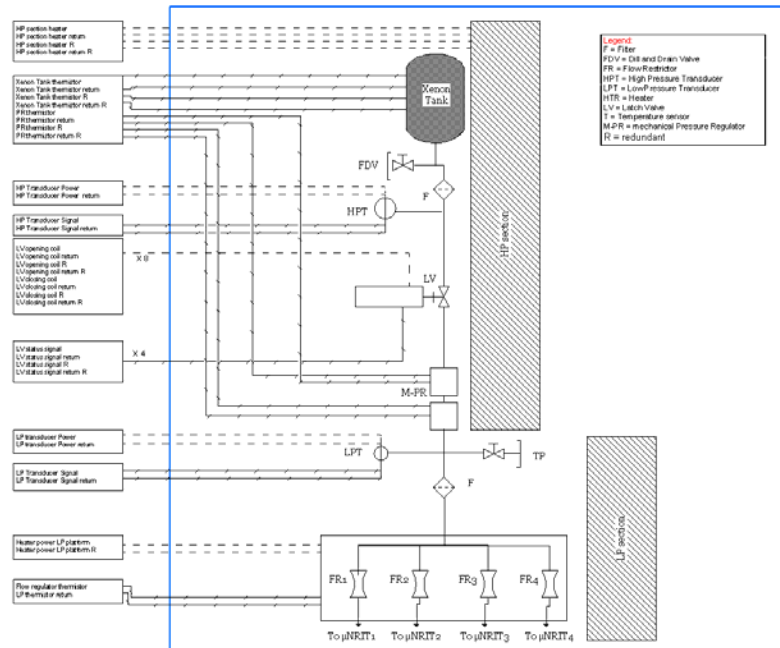


Figure 5: RIT XSFS architecture

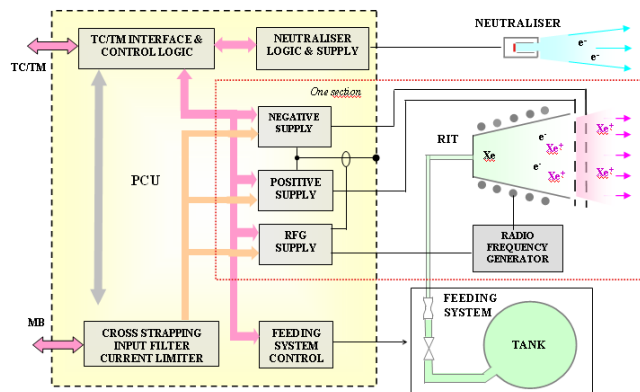


Figure 6: RIT PCU block diagram

produces a nominal electron current of 6 mA, suitable to counterbalance the electrical charge of up to 4 thrusters delivering each an ion beam current of 1.5 mA. The neutralizers are operated independently, and can be active at the same time, though normally they are operated one at a time: one is active and the other is cold redundant. The neutralizer design is based on a moderately high pervance propellant-less Electron Gun. Its principle of operation has been extensively described in previous papers [2]. Figure 7 shows one of the miniRIT RCA mounted on the external SCM panel.

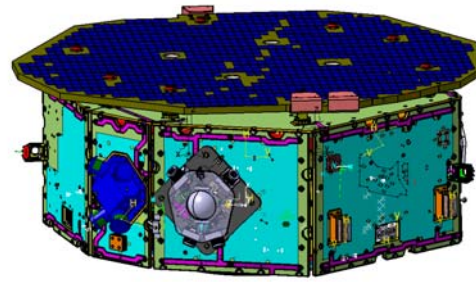


Figure 7: RCA accommodation on LPF SCM

IV. MiniRIT technology for LISA Pathfinder

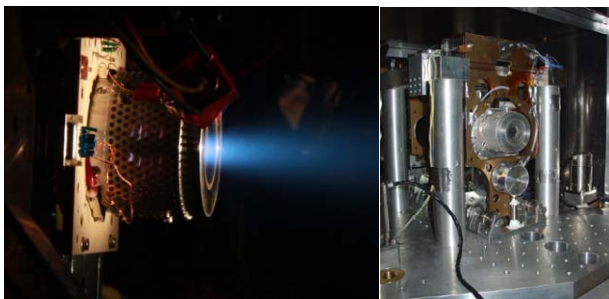


Figure 8: miniRIT in operation and installed on TASI Nanobalance

contract to a team composed by Astrium Lampoldshausen (D), Giessen University (D) and IOM (D) with the objective to design, build and test a miniaturised Gridded Ion Engine capable of delivering precise thrust modulation in the μN to low-mN range in order to satisfy several attitude and orbit control needs using a single thruster design concept. Three RIT- μX thrusters designs were proposed to respond to thrust requirement of $200\mu\text{N}$ -4mN (NGGM), $10\mu\text{N}$ - $150\mu\text{N}$ (Darwin, LISA) and $40\mu\text{N}$ - $500\mu\text{N}$ (PROBA3) [6]. To limit the development effort and to insure high flexibility of the thruster design it was agreed to proceed with a common ionisation unit design and exchangeable grids for each thrust range. The $40\mu\text{N}$ - $500\mu\text{N}$ design was selected for breadboarding and testing. This thruster has been extensively characterised via testing and results of the test have been presented in previous papers [7]. An extended firing test aiming at lifetime assessment was also performed. In 2009, Giessen University designed and built a smaller size, low power demanding thruster. This thruster was also extensively characterized via testing,

including thrust noise verification on the TASI Nanobalance [8]. In 2009 the development of the EM RIT- μX thruster was initiated.

In February 2011 Giessen University (D) and Astrium Lampoldshausen (D) have modified the existing miniRIT prototypes to adapt them to the LPF thrust requirements and performed a series of testing aiming at confirming the compliance to those requirements and to establish initial power demand figures for budget computation. Each prototype was operated at fixed flow rate. Test results are depicted in Figure 9.

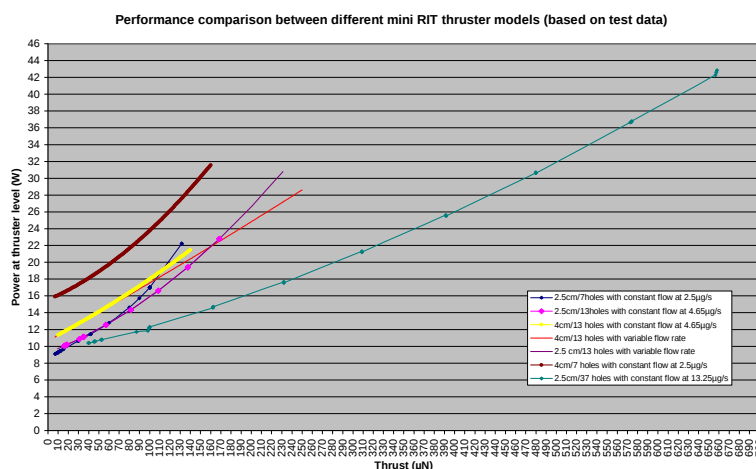


Figure 9: miniRIT thrusters' performance comparison

V. MiniRIT MPS budgets

A. Mass budget

Summary Mass Budget						
	Quantity pr Cluster	BEE Unit- or Specific Mass	BEE Mass pr Cluster	BEE Mass	Margin	Total with Margin
Ion Engine Unit	4	0.300	1.200	3.600	10.00%	3.960
RFG	4	0.550	2.200	6.600	10.00%	7.260
PCU	1	5.000	5.000	15.000	10.00%	16.500
Neutraliser	1	0.370	0.370	1.110	0.00%	1.110
Xe Tank	1	1.300	1.300	3.900	5.00%	4.095
HP Fill Valve	1	0.100	0.100	0.300	5.00%	0.315
HP Transducer	1	0.267	0.267	0.801	5.00%	0.841
HP Filter	1	0.088	0.088	0.264	5.00%	0.277
Isolation Valve	1	0.400	0.400	1.200	5.00%	1.260
Pressure Regulator	2	0.200	0.400	1.200	5.00%	1.260
LP Transducer	1	0.267	0.267	0.801	5.00%	0.841
LP Test Port	1	0.100	0.100	0.300	5.00%	0.315
Flow Restrictor	4	0.020	0.080	0.240	20.00%	0.288
Harness			0.262	0.786	20.00%	0.943
Pipework			0.244	0.731	20.00%	0.877
Structure			1.631	4.893	18.50%	5.798
Thermal h/w			0.100	0.300	20.00%	0.360
Dry			14.009	42.026	10.17%	46.301
Useable Xe			0.368	1.105	10.00%	1.216
Residual			0.019	0.058	10.00%	0.063
Loading Uncertainty				0.000	0.00%	0.000
Leakage			0.034	0.103	10.00%	0.113
Propellant			0.422	1.266	10.00%	1.392
Total Wet			14.431	43.292	10.17%	47.693
Offloaded FEFP			14.2263	42.68		44.147
Margin			-0.204	-0.613		-3.547

Figure 10: miniRIT MPS mass budget

ESA RIT MPS POWER MODEL											
Thrusters / cluster: 4											
POWER CONSUMPTION PR PCU MODE											
	ref	Fixed (W)	Linear (W/uA)	SB (W)	+N (W)	+RF (W)	+HV (W)	Thrust (W)	Max Thrust (W)	Min Thrust (W)	Max Thrust (W)
PCU	1	2.0000	0.0000	2.0000	2.0000	2.0000	2.0000	2.0000	2.0000	2.0000	2.0000
Xe Heater Power	1	5.5000	0.00000	5.5000	5.5000	5.5000	5.5000	5.5000	5.5000	5.5000	5.5000
Control Board1: ON	1	0.0000	0.00000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Control Board2: OFF	1	0.0000	0.00000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
PHV control	4	0.0000	0.00000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
NHV control	4	0.0000	0.00001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
RFG Control (BCC)	4	2.5000	0.00000	0.0000	0.0000	10.0000	10.0000	10.0000	10.0000	10.0000	10.0000
Pressure Transducer	2	0.0000	0.00000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Heater Power	2	0.0000	0.00000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Heater Control	1	0.3000	0.00000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000	0.3000
Neutralizer control	1	1.8000	0.00000	0.0000	1.8000	1.8000	1.8000	1.8000	1.8000	1.8000	1.8000
Neutralizer Supply	1	0.9000	0.00000	0.0000	0.9000	0.9000	0.9000	0.9000	0.9000	0.9000	0.9000
Neutralizer Bias Generator	1	0.0000	0.00000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
RFG 12V Supply	4	0.2667	0.00000	0.0000	0.0000	1.0667	1.0667	1.0667	1.0667	1.0667	1.0667
RFG 0.20V Supply	4	0.6314	0.00000	0.0000	0.0000	2.5256	2.5256	2.5256	2.5256	2.5256	2.5256
Local Dissipation			0.01040	5.8000	8.3000	21.8921	21.8921	22.1830	26.8911		
Neutralizer											
Beam Current (nA/uA)	4	0.02140	0.0000	0.0000	0.0000	0.0000	0.5990	8.5600			
Neutralizer Heater	1	2.5000	0.00000	0.0000	2.5000	2.5000	2.5000	2.5000	2.5000		
Neutralizer Anode	1	2.0000	0.00000	0.0000	2.0000	2.0000	2.0000	2.0000	2.0000		
Local Dissipation			4.5000	0.00000	0.0000	4.5000	4.5000	4.5000	4.5000		
RFG											
Internal Power Losses	4	3.2524	0.00000	0.0000	0.0000	3.4100	3.4100	3.5507	5.9420		
RFG Internal Control	4	2.4000	0.00000	0.0000	0.0000	9.6000	9.6000	9.6000	9.6000		
Local Dissipation			3.2524	0.00000	0.0000	13.0100	13.0100	13.1817	15.5487		
Thruster											
Ignition	4	5.6895	0.04730	0.0000	0.0000	22.7300	22.7300	23.9144	39.6500		
PHV	4	0.0000	0.00000	0.0000	0.0000	0.0000	0.0000	0.4644	6.4860		
NHV	4	0.0000	0.00000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000		
Local Dissipation			5.6895	0.05658	0.0000	22.7300	22.7300	24.3700	46.1620		
TOTAL											
				5.8000	12.8000	58.7221	58.7221	60.6544	86.3113		

Figure 11: miniRIT MPS power model

B. Power Budget

On Lisa Pathfinder the 12 miniRIT thrusters shall be used for attitude control and station keeping. Therefore thrust levels will be time varying and vary from thruster to thruster throughout the mission. Making the simplifying assumption that all thrusters fire at maximum thrust all the time would be a worst case for sizing, but would also render the system infeasible due to exaggerated resource needs. The approach taken was to consider each mission phase individually, establish resource availability, the AOCS mode used, required thrust authority and thermal control needs. The mission phases of relevance are those during which the MicroPropulsion Subsystem is needed, starting from its commissioning. The miniRIT MPS power demand has been computed by modeling the consumption in terms of the fixed losses and a load proportional to the generated thrust. The power

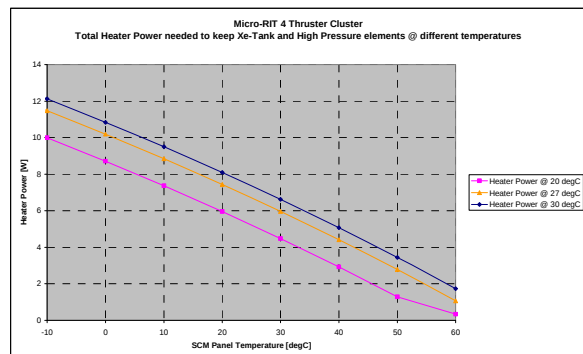


Figure 12: miniRIT MPS thermal budget

drawn by the PCU from the system bus is converted to high voltage power for the grids and control voltage for the RFG. The efficiency of this process leads to losses that constitute together with the control electronics losses the heat loss at PCU level. The RFG control signal is converted to RF power in the RFG, with efficiency losses that leads to additional heat dissipation at this level. Finally, the RFG output RF power and PCU output high voltage power is converted to work in the form of thrust in the MiniRIT. The test performed with the thrusters together with their RF generators had allowed measuring directly the consumption at PCU output. Such tests cover therefore any uncertainties associated with RFG conversion of DC current to RF power, ionization in the thrust chamber, and grid performance. The cluster level power model is summarized in Figure 11. This model is built in function of the thrust level and number of thruster operating (i.e. firing) to accommodate different subsystem configurations but does not include the power needed for thermal control which has been computed as result of the thermal analysis. Figure 12 provides the heater power needed to maintain the Top-plate and the Xe-tank at 20 and 30 degC when the SCM panel temperature varies from -10 to 50 degC.

The power available from solar array output is 679W, except during de-spin and safe mode where 556W is assumed. Figure 13 shows the power available per mission phase after switching off the FEED MPS. The net power available for thruster operation, after subtracting the power needed for thermal control and the power required by each PCU is reported in Figure 14. The unrealistic condition of contemporary firing all thrusters at maximum thrust in all phases, will lead to a negative power budget. In order to reduce the MPS power demand a solution has been found to reduce the number of operating thrusters down to 8 thrusters.

	Available Power											
	SGS	5%	System Load	w/o FEED MPS	FEED MPS	System Reserve	Available	Harness	PCU			
	REE	w/margin	REE	w/margin	REE	w/margin	REE	w/margin	REE	w/margin	REE	w/margin
MPS Commissioning	679.0	646.7	638.2	644.5	471.8	478	166.4	166.5	40.8	2.3	307.2	168.7
Cruise	679.0	646.7	689.8	686.0	473.9	480	115.9	116.0	89.2	50.7	206.1	166.7
Spin Up	679.0	646.7	465.7	471.3	465.7	471.3	0.0	0.0	213.3	175.4	213.3	175.4
Demutate, Despin, Sun Acquisition	556.0	529.5	476.0	481.7	263.1	268.8	192.9	192.9	80.0	47.8	272.9	240.7
Attitude Acq. & Slew for MGA	679.0	646.7	476.0	481.7	263.1	268.8	192.9	192.9	203.0	165.0	396.9	357.9
L1 Acquisition	679.0	646.7	476.0	481.7	263.1	268.8	192.9	192.9	203.0	165.0	396.9	357.9
LTP Switch-On	679.0	646.7	600.4	605.2	386.1	410.8	184.1	184.5	98.6	51.0	262.7	235.9
Caged Station Keeping	679.0	646.7	476.0	481.7	263.1	268.8	192.9	192.9	203.0	165.0	396.9	357.9
LTP Commissioning	679.0	646.7	593.0	607.6	414.6	429.1	178.5	178.5	96.0	39.1	264.5	217.6
LTP Science	679.0	646.7	593.0	607.6	414.6	429.1	178.5	178.5	96.0	39.1	264.5	217.6
DRS Commissioning	679.0	646.7	593.0	607.6	414.6	429.1	178.5	178.5	96.0	39.1	264.5	217.6
DRS Science	679.0	646.7	593.0	607.6	414.6	429.1	178.5	178.5	96.0	39.1	264.5	217.6
DFACS Station Keeping	679.0	646.7	547.4	558.0	330.1	340.7	217.3	217.3	131.6	88.7	348.9	306.0
Safe Mode Entry	679.0	646.7	546.2	553.0	368.7	365.4	187.5	187.5	132.8	93.7	320.3	261.3
Safe Mode Waiting (MSAM)	679.0	646.7	546.2	553.0	368.7	365.4	187.5	187.5	132.8	93.7	320.3	261.3
Safe Mode Waiting (MNM)	679.0	646.7	546.2	553.0	368.7	365.4	187.5	187.5	132.8	93.7	320.3	261.3

Figure 13: System Power Available

	Power Synthesis			Net for Power Available for thrust vs. # of thrusters							
	Available	TCS	PCU	Thrusters	7	8	9	11	12		
	(W)	(W)	(W)	(W)	(W)	(W)	(W)	(W)	(W)		
MPS Commissioning	165.3	32.3	38.58	94.4							
Cruise	163.3	35.9	17.4	110.0							
Spin Up	171.9	35.9	38.58	97.4							
Demutate, Despin, Sun Acquisition	235.9	22.7	38.58	174.6	88.5	76.2	63.9	39.3	27.0		
Attitude Acq. & Slew for MGA	350.7	22.7	38.58	289.4	203.3	191.0	178.7	154.1	141.8		
L1 Acquisition	350.7	19.2	38.58	292.9	206.8	194.5	182.2	157.6	145.3		
LTP Switch-On	231.1	24.0	38.58	168.6	82.5	70.2	57.9	33.3	21.0		
Caged Station Keeping	337.1	23.7	38.58	274.8	188.7	176.4	164.1	139.5	127.2		
LTP Commissioning	213.2	24.0	38.58	150.6	64.5	52.2	39.9	15.3	3.0		
LTP Science	223.7	24.0	38.58	167.1	81.0	68.7	56.4	31.8	19.5		
DRS Commissioning	178.7	25.7	38.58	114.4							
DRS Science	266.5	34.9	38.58	193.0							
DFACS Station Keeping	298.8	23.8	38.58	237.5	151.4	139.1	126.8	102.1	89.8		
Safe Mode Entry	275.6	24.6	38.58	212.5	126.3	114.0	101.7	77.1	64.8		
Safe Mode Waiting (MSAM)	275.6	24.6	38.58	212.5	126.3	114.0	101.7	77.1	64.8		
Safe Mode Waiting (MNM)	275.6	23.7	38.58	213.4	127.2	114.9	102.6	78.0	65.7		

Figure 14: Summary Power Budget

VI. Conclusion

The miniRIT MPS has been found to be a viable alternative to the FEED MPS to achieve all LISA Pathfinder mission objectives. All system margins have been retained in this study, and adequate margins are provided at subsystem level. The preliminary design has not identified any immediate show-stoppers. Previous missions using RIT technology have generated a significant amount of know-how and technology readiness at higher thrust levels, and scaling this down to LPF mission needs has already been initiated and is considered a low risk extension of current knowledge.

As consequence of the study results, ESA has requested ASTRIUM Ltd, LISA pathfinder Prime Contractor, to consolidate the findings by performing a preliminary design and all other necessary activities to remove all residual technical and programmatic risks before starting the subsystem procurement. Within this frame it is foreseen to achieve the RIT MPS subsystem PDR by January 2012.

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