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REQUIREMENTS AND TRADE-OFF STUDIES IN SATELLITE MECHANICAL ARCHITECTURE

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RESUMO-NOTAS/ABSTRACT-NOTES

This paper presents the requirements and trade-off studies used in the architectural concept design phase of the MECB-RSS1 satellite. The main necessary requirements are presented with four satellite configurations designed to meet all of them. The desirable requirements are presented with the trade-off methodology used to choose between those different configurations. The present design phase configuration is also shown.

OBSERVAÇÕES/REMARKS

This paper has been presented to the 1st Brazilian Symposium of Aerospace Technology, Aerospace Technology Institute, São José dos Campos, 27-31 August, 1990.

**REQUIREMENTS AND TRADE-OFF STUDIES
IN SATELLITE MECHANICAL ARCHITECTURE**

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SUMMARY

This paper presents the requirements and trade-off studies used in the architectural concept design phase of the MECB-RSS1 satellite. The main necessary requirements are presented together with four satellite configurations designed to meet all of them. The desirable requirements are presented with the trade-off methodology used to choose between those different configurations. The present design phase configuration is also shown.

CONFIGURATION REQUIREMENTS

The requirements to be necessarily complied (numerically quantified) by the RSS1 satellite mechanical architecture, whose orbit configuration is presented in Fig -1 at its concept design phase (Ref. 1) were:

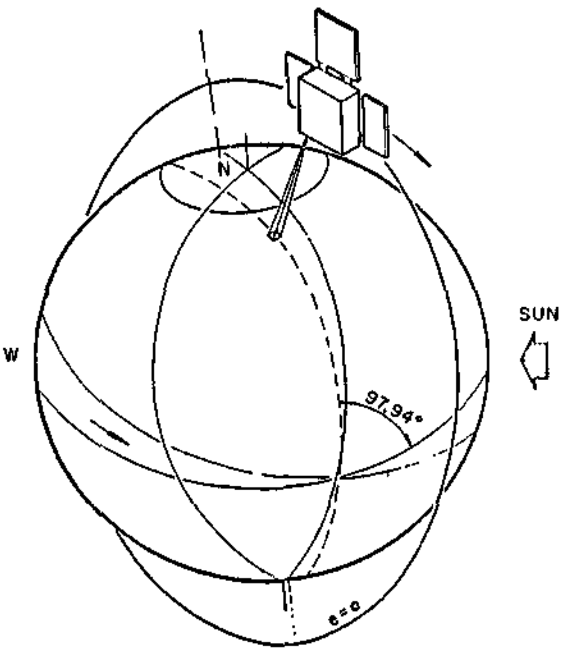

Fig - 1 - Orbital Configuration.

Launch Vehicle Interface Requirements:

- Total Launch Mass = 170 Kg. (Present: 200 Kg)
- Other Mass properties: Z axis product of inertia less than 36500 Kgcm2. Mass unbalance: 0,8 Kgcm
- Stowed configuration limits: Available volume under as dimensioned in Fig -2-
- Circular flange launcher adaptor of approximately 260 mm diameter.
- Mechanical environment. A summary of the main load factors and are shown in Table 1 and 2.

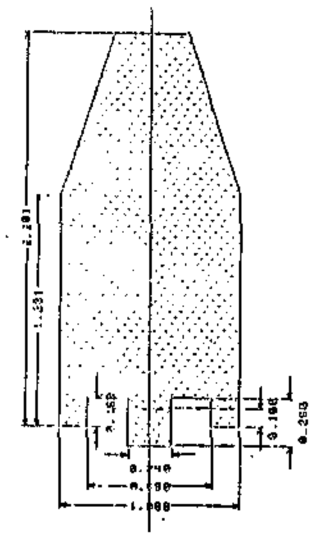

Fig -2- Available Launcher Heatshield Space.

Table - 1 - LAUNCH "QSL" LOAD FACTORS (q)

FLIGHT EVENT	LONGITUDINAL AXIS	LATERAL AXIS
Max. Dyn. Pressure	+ - 3.5	+ - 5.0
4th Stg. End of Burn	- 12.0	+ - 1.0
+Spin: Speed = 15.8 rd/s-1 Accel. = +15.0 rad/s-2		
"Additional" case	- 5.0	+ - 3.5

Obs.: The minus sign indicates compression.
Lateral and longitudinal loads are simultaneous.
QSL loads apply uniformly all over spacecraft.

Table - 2 - PRE-LAUNCH LOAD FACTORS (q)

EVENT / DIRECTION:	VERTICAL	HORIZONTAL	MOVEMENT
Hosting	-3.0 + 2,5	+-0.5	---
Transportation	-4.0,+2.0	+-2.5	+-3.0

Obs.: The +-3.0 load factor in the movement direction is to over rail-road transport. Satellite load factors will depend on transport position.

Power system requirements:

- Minimum solar array available area of 1.7m2 (Present: 2.1 m2)
- Solar panels deployment without powered motors.
- Accommodations for two batteries. (Present: one)

A.O.C.S. Requirements:

- Satellite CG travel along z axis (= TBD.)
- Trusters control torques (1.8 Nm.)
- Earth sensors field of view : 60 deg.
- Coarse solar sensors view field: 2 pi stereo radians
- Fine solar sensors field of view: 60 deg.
- TBD Alignment requirements (rigid panel mounting) for: Horizon Sensors, Fine Solar Sensors, Rough Solar Sensors, Reaction Wheels, Trusters and Gyro Pack

Telemetry requirements:

- Two S Band antennas covering each a 2 pi unobstructed angle during acquisition phase.
- One S Band antenna with a 120 deg. unobstructed earth view.

Propulsion Requirements:

- 26.6 l tank(s) volume for hydrazine.
- Redundancy of thrusters and of their feed lines.

Integration Requirements:

- A minimum of 45 mm free space in front of each equipment connector.
- Eight hard points to install balance masses of up to 1 Kg.
- A minimum of six hard points for satellite transportation in upright and laid-down positions.

Payload Requirements:

- Lens field of view (F.O.V.): 58.8 deg.
- Camera alignment: TBD.

PROPOSED CONFIGURATIONS.

Four SSR1 satellite architectures complying with all the specified "necessary" requirements were developed and their orbit configuration are shown in Figures 3 to 6.

Sketches of possible internal lay-outs for configurations 1A and 2A are presented in Figures 7 and 8 and the corresponding computed mass properties are given in Table 3.

TABLE - 3 -Configuration 1A and 2A mass parameters.

CONFIGURATION		1A LAUNCH.	1A ORBIT	2A LAUNCH.	2A ORBIT
MASS PARAM.					
	X c.m.	+0.001	+.001	-0.002	-0.002
C.M.	Y c.m.	-0.003	0.009	+0.001	+0.008
	Z c.m.	0.569	0.591	0.552	0.575
	Ixx	18.9	22.8	19.1	22.0
M.I.	Iyy	27.0	31.6	21.9	26.8
	Izz	14.0	14.9	12.8	17.7
P.I.	Izx	-0.3	-0.3	0.1	0.1
	Izy	0.8	0.1	-0.5	-1.5

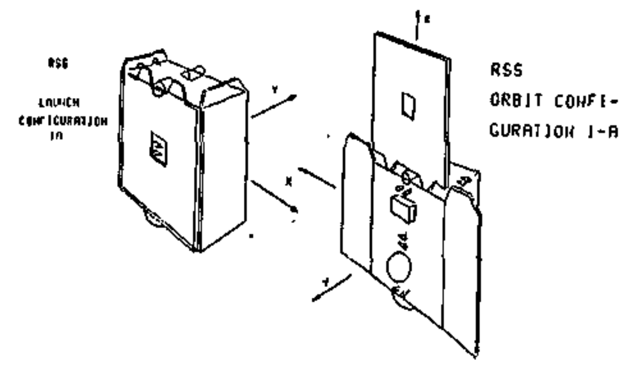

Fig - 3 - Configuration 1A

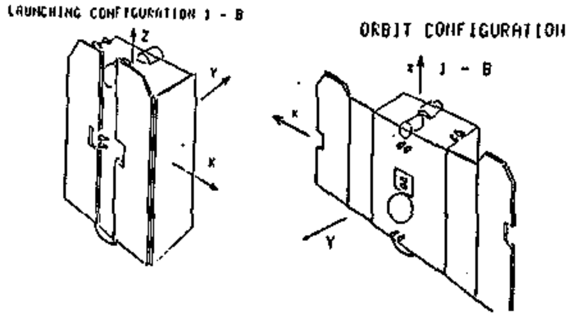

Fig - 4 - Configuration 1B

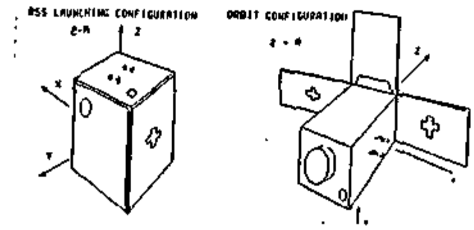

Fig - 5 - Configuration 2A

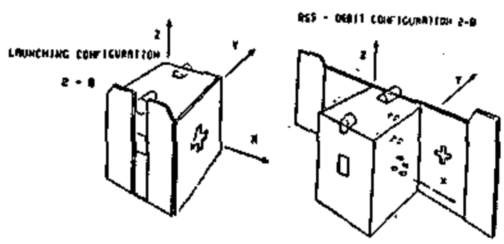

Fig - 6 - Configuration 2B

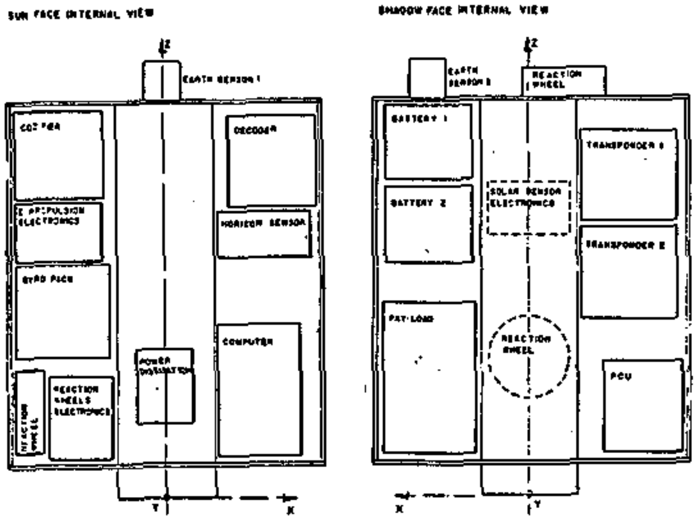

Fig - 7 -Configuration 1 internal lay-out

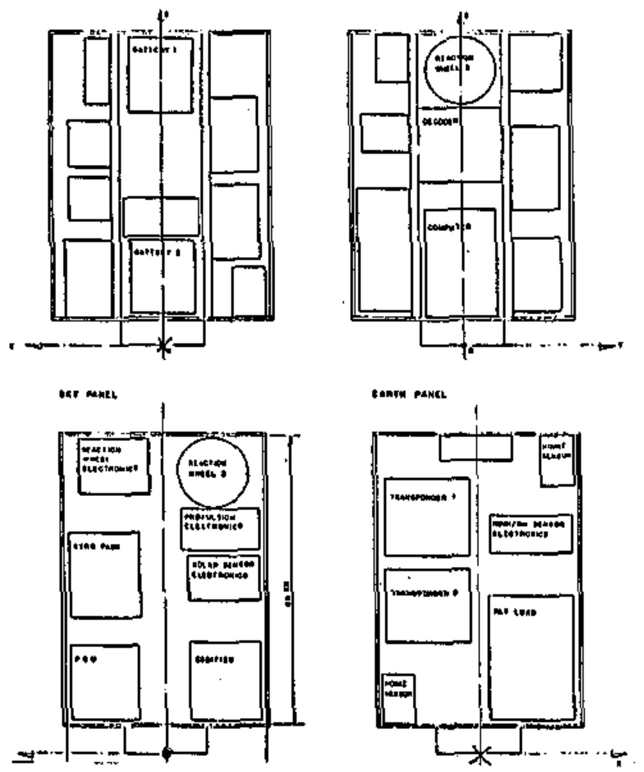

Fig - 8 - Configuration 2 internal lay-out.

CONFIGURATION TRADE-OFF ANALYSIS

The merits of each proposed configurations are to be compared by means of a trade-off analysis, considering all the "desirable" or qualitative requirements.

This analysis follows the "Kepner Tregoe" methodology (Ref. 1) using the desirable requirements applicable to the SSR1 which are presented and numbered as follows:

Mission. 1.1 Mass and volume increase possibility.
Requirements: 1.2 Low drag.
1.3 Low perturbation torques.

Thrusters 2.1 Low plume impingement on panels.
Arrangement: 2.2 Short fuel lines.
2.3 Internal lay-out flexibility.

Solar Panels 3.1 Mechanical simplicity.
Requirements: 3.2 Area (power) increasing possibility.
3.3 Small C.M. travel.

Integration 4.1 Equipment accessibility.
Requirements: 4.2 Modular assembling and testing.

Structure & 5.1 Structural low weight.
Thermal C. : 5.2 Internally mounted equipments.

Each requirement received a "weight", and the configurations were "scored" as function of its requirement fulfilling capability.

To better evaluate the weight of each requirement a weighting matrix procedure shown in table 4 was used.

In this procedure, each desirable requirement is confronted individually with each other, the winner receiving 2 and its opponent 0. In case of even results or when no relationship or confrontation can be found, both requirements receive 1.

The sum of requirement points is normalized in the weight range 1-5.

Table - 4 - Desirable Requirements Weighting Matrix.

	1.1	1.2	1.3	2.1	2.2	2.3	3.1	3.2	3.3	4.1	4.2	5.1	5.2
1.1	-	2	2	0	2	2	2	0	0	2	2	2	2
1.2	0	-	2	0	2	0	0	0	0	0	0	0	0
1.3	0	0	-	0	2	0	2	0	0	1	1	0	2
2.1	2	2	2	-	2	2	2	2	2	2	2	0	0
2.2	0	0	0	0	-	0	0	0	0	0	0	2	2
2.3	0	2	2	0	2	-	0	0	0	0	0	2	0
3.1	0	2	0	0	2	2	-	0	0	0	0	1	2
3.2	2	2	2	2	0	2	2	-	2	1	1	2	2
3.3	2	2	2	0	2	2	2	0	-	0	0	0	2
4.1	0	2	1	0	2	2	2	1	2	-	0	0	2
4.2	0	2	1	0	2	2	2	1	2	2	-	2	2
5.1	0	2	2	2	0	0	1	0	2	2	0	-	2
5.2	0	2	0	2	0	2	0	0	0	0	0	0	-
Peso	5	1	2	5	1	2	2	5	4	4	5	4	2

With the weights so determined the trade off between all configurations is presented in Table 5 in which each configuration was scored according to the criteria:

The baseline 1A configuration received the note 3 for all requirements and the other received notes above or below 3, according to:

If inferior to configuration 2A: Note 1
If worse than configuration 2A: Note 2
If better than configuration 2A: Note 4
If superior to configuration 2A: Note 5

Table - 5 - Satellite Configuration Trade-off

REQUIREMENT:	NOTE				WEIGHT	NOTE x WEIGHT			
CONFIGUR.:	1A	1B	2A	2B		1A	1B	2A	2B
1.1	3	3	4	4	5	15	15	20	20
1.2	3	3	1	1	1	3	3	1	1
1.3	3	5	3	5	2	6	10	6	10
2.1	3	3	4	4	5	15	15	20	20
2.2	3	3	5	5	1	3	3	5	5
2.3	3	3	5	4	2	6	6	10	8
3.1	3	1	3	1	2	6	2	6	2
3.2	3	3	4	4	5	15	15	20	20
3.3	3	4	3	4	4	12	16	12	16
4.1	3	3	5	5	4	12	12	20	20
4.2	3	3	2	2	5	15	15	10	10
5.1	3	3	2	2	4	12	12	8	8
5.2	3	3	5	5	2	6	6	10	10
TOTAL SCORE...........................						126	130	148	150

The given qualitative notes are then discussed in detail, for each desirable requirement:

1.1 requirement: Since configurations 2A/B have a internal volume 37% larger (.47 m3) than configurations 1A/B (.34 m3) they were considered to be better than the nominal.

1.2 requirement: An estimate of the drag coefficient for configuration 2A/B was made based on existing Cd = 3.8 value already computed for configuration 1A/B. A Cd value of 3.09 was found, which due to the higher frontal area resulted in a increase of 21% in total drag for the 2A/B configurations, so were considered to be inferior to configurations 1A/B.

1.3 requirement: Since configurations 1B and 2B are symmetrical, they have negligible perturbation torques and so were considered superior to 1A and 2A configurations.

2.1 requirement: In configurations 1A/B we have a high degree of plume impingement from yaw trusters on the solar cells face of the lateral solar panels. In configurations 2A/B all thrusters have a clearance of at least 20 cm from the back face of the solar panels so they were considered better than 1A/B configurations.

2.2 requirement: Configuration 2A/B will need about 9.5 meters of hydrazine carrying tubing while in configuration 2A/B only 4.5 meters will be needed and in consequence were considered superior.

2.3 requirement: In configuration 2A thrusters can have different thruster arrangements while in 1A/B configurations, yaw thrusters are "frozen" and pitch thrusters can not be moved without solar panel cut-outs. Configuration 2A was so considered better and 2B superior to nominal.

3.1 requirement: 1B and 2B configurations require at least doubly hinged solar panels which mechanically are considered more complex and less reliable than configuration 1A and 2A single hinged panels and so 1 an 2 B were rated inferior to nominal.

3.2 requirements: Configurations 2A/B solar panels besides being .24 m2 larger than configurations 1A/B ones (hardly meeting the 1.7 m2 minimum requirement) they can be increased of .38 m2, being so better than nominal.

3.3 requirement: THe solar panels opening causes c.m. shifts that are listed below:

Configuration	1A	1B	2A	2B
Y shift (mm)	12	12	7	10
Z shift (mm)	22	0	20	0

In consequence configurations 1B and 2B are considered better than the nominal and 2A equal.

4.1 requirement: The equipment accessibility and integration easiness are greatly enhanced in configurations 2A/B due to their removable covers. In addition, all alignment requiring equipment support panels are structurally fixed while in configurations 1A/B they must be removed to permit equipment access being difficult to comply with alignment specs. 2A/B configurations are so considered superior in this requirement.

4.2 requirements: In configurations 1A/B this integration procedure can be applied, but only to two modules. In configurations 2A/B a completely separate integration and testing will not be possible but equipment can be arranged in four separate equipment bays and in consequence they are considered only worse than nominal.

5.1 requirements: In 2A/B configurations the additional weight of the four covers (3.6 Kg) and of the two lateral equipment panels (3.0 Kg)will be partially compensated by a lower weight of the two smaller dimension main structural panels (-3.0 Kg) and much shorter central tube and webs (- 1.5Kg). In consequence they are rated only worse than nominal. The small weight increase due to the double hinged solar panels of configurations 1 and 2 B was not considered to affect the scores.

5.2 Requirement: This requirement is not met by the nominal and 2B configurations in which some equipments in special two reaction wheels will need to be externally mounted. In consequence 2A/B configurations are considered to be superior to the nominal.

ADVERSE EVENTS ANALYSIS

A trade-off analysis of desirable requirements must be complemented by an adverse events analysis (simplified reliability estimate).

In this, each probable adverse event is weighted (1-5) in function of the negative impact of its occurrence and scored by the product of this weight by the estimated probability of its occurrence in each configuration.

A first adverse event considered was the blocking of solar panels hinges resulting in frozen panels.

A second one was the satellite entering in a "flat spin" movement.

Since the satellite rotational speed is quite small, (.66 rph) and the slosh of the hydrazine is avoided by the tanks membranes, the time necessary to go out of control from nutation to a "flat spin" is estimated to be long and so this event probability was estimated to be low.

Although only configurations 2A/B can enter a badly oriented flat spin, the total adverse events score was only slightly changed by this event.

Table - 7 - ADVERSE EVENTS ANALYSIS

CONFIGURATION		1A	1B	2A	2B
EVENT	WEIGHT	ESTIM.	PROBABILITIES		(%)
Frozen Solar Panels	5	2	4	2	4
Satellite Flat Spin	2	0	0	1	1
Total Score		-10	-20	-10.2	-20.2

For the SSR1 the frozen panel adverse event was found to discriminate between the 2A and 2B configurations which presented desirable requirement scores of the same order, and it determined the final choice of the 2A configuration.

CONFIGURATION EVOLUTION

As in all long term projects, the chosen configuration is far from be frozen before all subsystem designs are in a mature phase .

The present status of the chosen configuration and present internal lay-out are given in Fig. 9 and 10.

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1. Documento MECB: A-REV-1000 - Remote Sensing Satellite Concept Review, Vol II, Instituto de Pesquisas Espaciais, Abril 1988

2. Manual do Planejamento de Resultados. Apostila do curso "APEX" Kepner Tregoe and Associates Inc - 1985

3. Documento A-CFG-1000 - SSR1 Configuration Status, Instituto de Pesquisas Espaciais, Junho 1990.

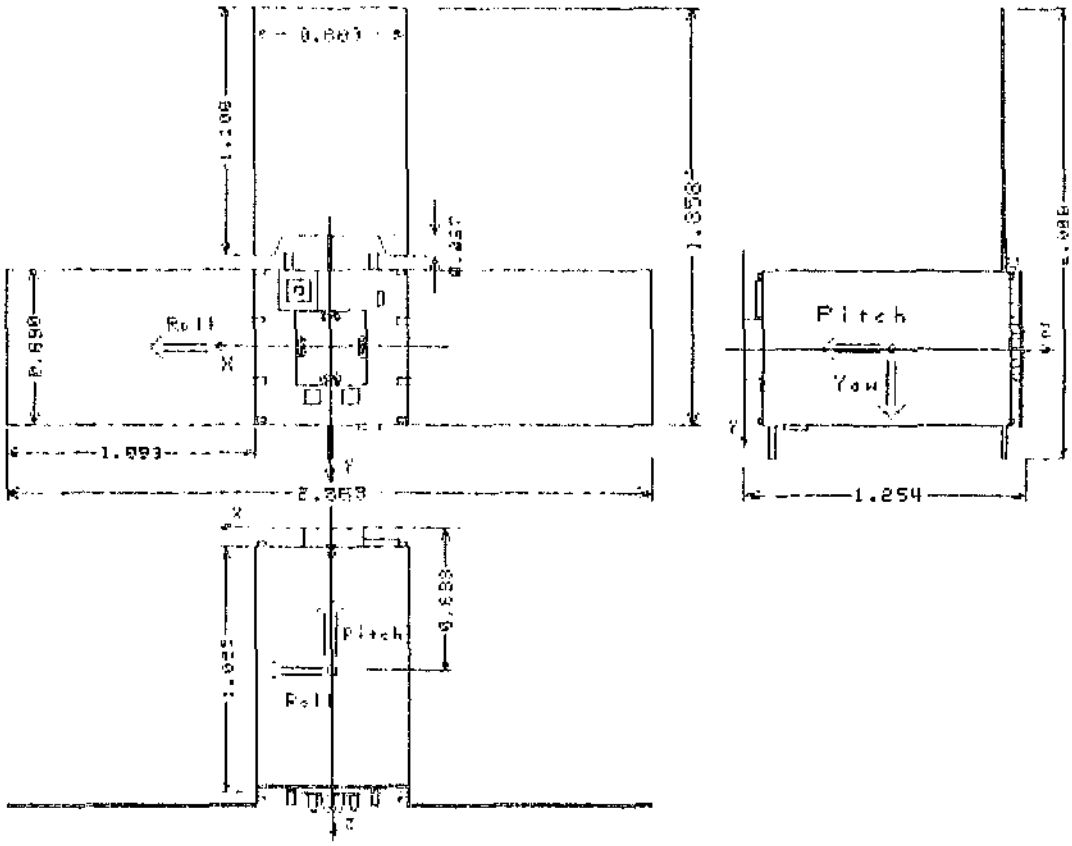

Fig - 9 - Present SSR1 orbit configuration.

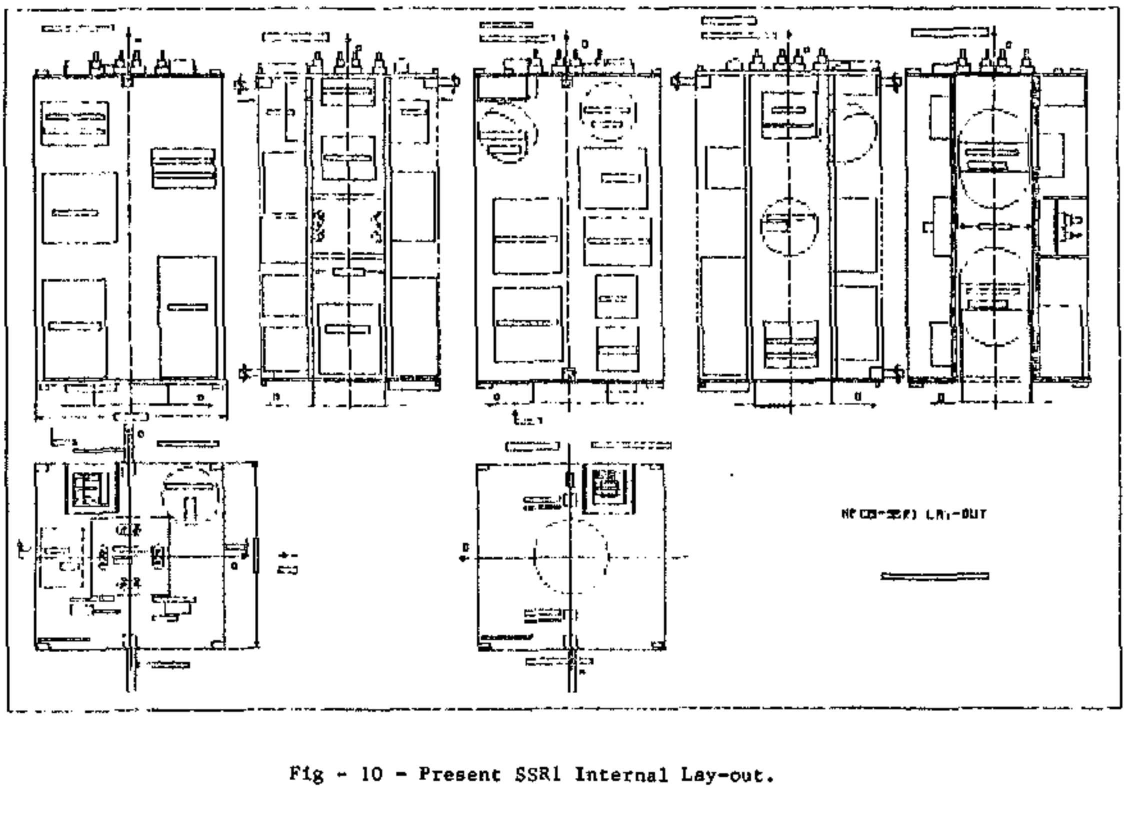

Fig - 10 - Present SSR1 Internal Lay-out.

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