A COMPACT SADM FAMILY

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ABSTRACT/RESUME

Alcatel Space has developed a new SADM family driven by cost, modularity, mass and performances. The modularity concept is based on separating the rotation drive function from the electrical transfer function. The drive actuator has been designed for various applications where pointing and reliability is needed. It can be associated with high dissipative rotary devices (SA collectors, RF joints…).

The design goal was to minimize the number of parts in order to reach the most simple and compact mechanism. Mass reduction was achieved by reducing as much as possible the load path between the Solar Array interface and the spacecraft interface.

Following these guidelines, the drive actuator was developed and qualified on ATV SADM (part of Alcatel Space Solar Array Drive Sub System for ATV). Further more a high power integrated collector was qualified inside the SADM for Geo-stationary telecom satellite (SPACEBUS platforms).

Fine thermal and mechanical modeling was necessary to predict SADM behaviors for the numerous thermal environments over the missions (steady and transient cases). These modeling were well correlated through mechanical and thermal balances qualification tests.

The challenging approach of thermal dissipation in a compact design leads to a family of 3 SADM capabilities form 2kW up to 15kW per SADM weighing less than 4.5 kg each.

INTRODUCTION :

In the end of 90's, Alcatel started the development of SADM through bread boarding first and followed by proposals for SKYBRIDGE constellation, ATV program and SPACEBUS applications. When the SKYBRIDGE program stopped, all the development breadboard experiences were reused for the ATV and SPACEBUS developments. Faced to the various requirements of ATV (very low power) and SPACEBUS spacecraft power range (low to high), we decided to develop a SADM family. Further more, other space applications call for rotative devices in order to move various objects (RF joint, cable wrap…). Consequently, the SADM concept was driven by modularity.

To satisfy this challenge, a drive unit was developed offering a traversing hole with interfaces on the stator and rotor sides. The various collectors of the SADM family have the same interfaces with the drive unit.

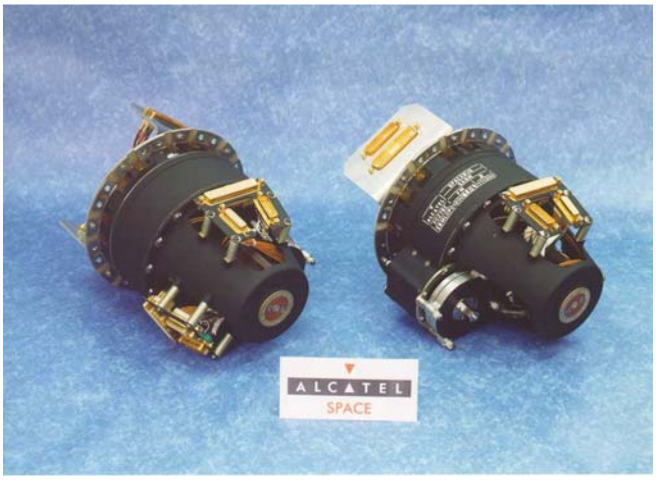


Fig. 1 : FM GEO LOW POWER SADM

Fig. 2 : FM LEO SADM

REQUIREMENTS FOR THE SADM FAMILY:

The main requirements of specification are :
* to drive LEO Solar array of 4 panels (3.2 kg.m² with 3,7 kW electrical power), and GEO Solar array of 3 panels (30 kg.m² with 4,5 kW electrical power) up to 10 panels (500 kg.m² with 80 m² of solar cells with 15kW electrical power) from SOLARBUS range of Solar arrays

Fig 3 : SOLARBUS 10 panels

* to maintain Solar Array under maximum loads of 500N radial; 200N axial and 300 N.m bending or/and 5kg of 44 up to 115 mm from SA I/F under vibration and shock environments.
* transfer Solar Array power and signals :
 - 32 power signal (1.3 A under 90V); 4 groundings and 12 signal lines
 - from 9 up to 20 sections (7,5 A max under 100 V each); 3 to 5 return lines, 20 lines of TM/TC for Solar Array.

CONCEPT :

The SADM is composed of a drive unit and a collector with its associated cover adapted to the mission.

The SADM Rotary Actuator Drive Unit features a the spur gear which allows a simple design concept.
The stepper motor is mounted on two back to back ball bearings associated to a one stage spur gear .
One main ball bearing at output section level transfers loads between the solar array and the spacecraft with the shortest load path.
One potentiometer is used to provide the feedback position of the SADM output shaft.
One optional reset switch provides the SADM electrical reference position.

A collector (also called slip ring) is mounted inside the drive unit to transfer power and signals between the rotating solar array and the spacecraft. These collector are based on gold to gold technology. To fit with the SADM Family requirements, 3 collectors have been developed and qualified :
- a small one for LEO application (32 power lines and 12 signal lines)
- a medium one for low power GEO application (18 power lines of 5A max each under 100 V)
- a large one for high power GEO applications (20 power lines of 7,5A max each under 100V)

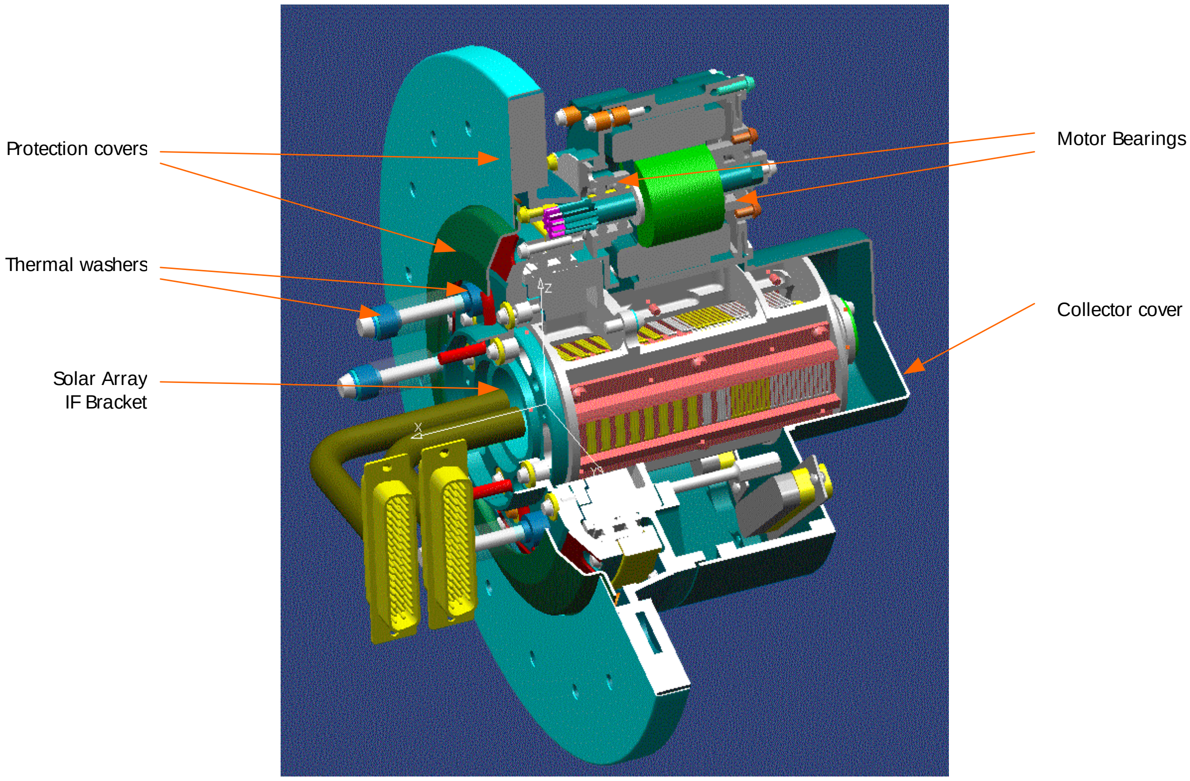


Fig. 4 : SADM view

Main advantages of the design:

- compact and simple design
- the load path is very short between the Solar Array I/F and the platform I/F. The collector doesn't participate to the SADM stiffness
- the major sensible component of the SADM (gear, potentiometer, optical switch) are close to the main ball-bearings in order to limit the amplification factor during vibrations.
- the ball-bearing diameter enables the optimisation of the SADM length by providing space for the collector assembly inside the Rotary Actuator Drive.
- the drive unit can be assembled separately from collector. Drive units can be assembled in advance. Final collector integration can be performed later.

Fig.5 : Drive unit and its Geo low power collector

Based on this concept, the development phase was faced to various problems. Because this mechanism is a compromise between mechanical and thermal constrains, we had to make several iterations to obtain analysis results which seemed reasonable. For instance, due to the fact that this mechanism is at the frontier of the spacecraft and space, there are lot of thermal gradient inside of it. The calculation of the thermal gradient inside the main bearing needed bread boarding validation in order to adjust the thermal model and the associated effects on SADM performances.

All the SADM mechanisms have been modelled in detail with almost 400 thermal nodes. Internal conductive and radiative couplings have been considered, for fixed and moving elements. The thermal modeling and control of such condensed and dissipative equipment was a challenge, in terms of temperature levels / in homogeneity and modeling accuracy. Several parts have internal dissipation : the motor, when SADM rotation is activated; the collector when current is collected from solar array. These dissipative elements have non conventional contact and fixing characteristics. Due to these specificities, several assumptions have been made for rotor/stator and ball bearing couplings. The thermal model has been permanently improved with refined nodal breakdown. The couplings hypothesis have been correlated with 11 thermal balance cases. The definition of each case is a result of a system approach to identify the sizing cases when 5 interfaces conditions are specified in 10 different orbital modes with 8 current levels per mode. There are many ways to correlate a complex thermal model such as SADM one. This is why correlations were made over numerous cases (the overall cases corresponding to each specific thermal behaviour) : thermal assumptions are such that a specified case can be fully correlated whereas another one can lead to non physical results.
Thanks to this correlation campaign, the SADM thermal model is fully accurate for all cold and hot mission phases, from Transfer up to Geostationnary orbits. Moreover, eventual future SADM developments will benefit of this competence and knowing, by using already correlated couplings and model parts for dimensioning and thermal test predictions.

The qualification of the SADM has been successful in part thanks to a good knowledge of the mechanism structural behavior and specially of the motor air gap variations under thermal and mechanical environments. That knowledge was obtained through simulations (Finite Element Model) which have been improved and correlated all along the development phase taking into account vibrations and thermal tests results.
The final FEM used for dynamic and thermo-elastic predictions is represented hereunder :

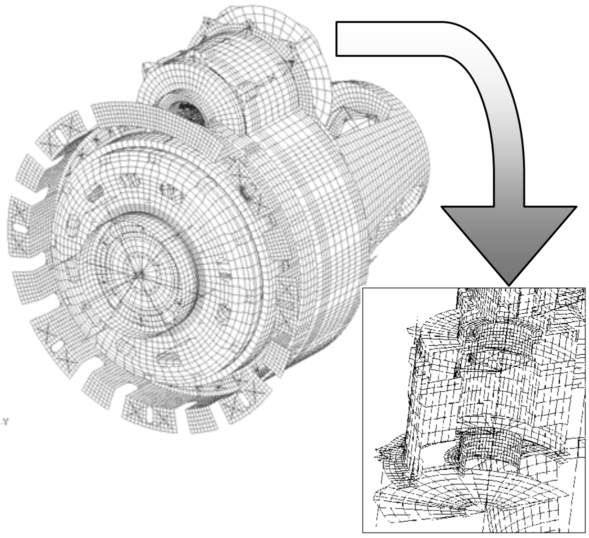
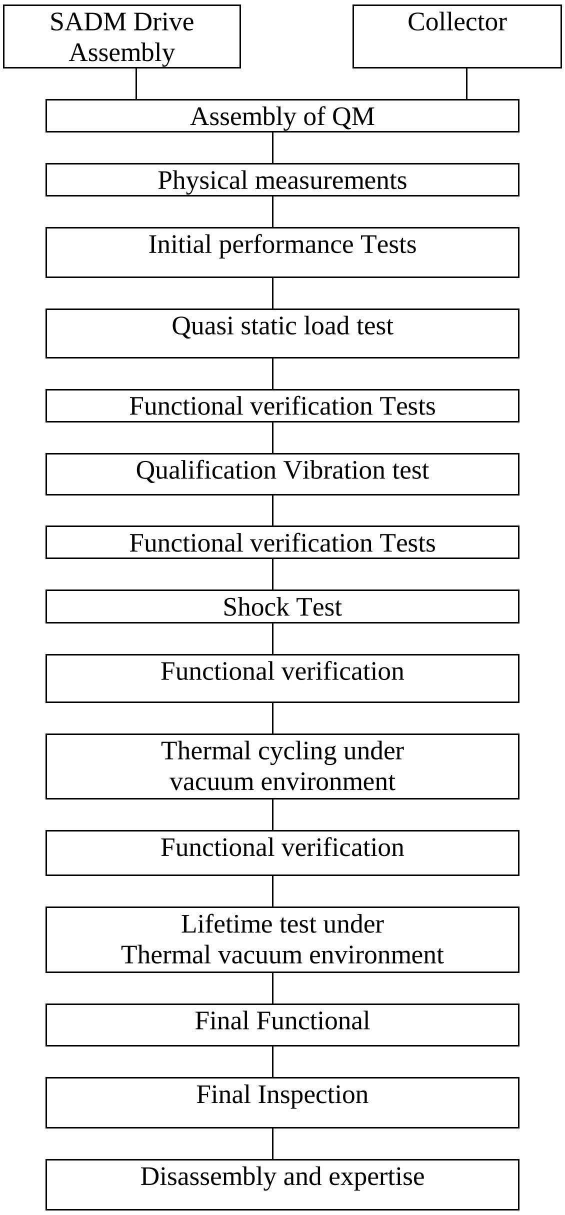


Fig. 6 : SADM model

DEVELOPMENT PHILOSOPHY :

In order to qualify this SADM family, we identify 2 Qualification model, one for LEO, one for GEO applications.
Each QM, assembled with the flight as design, have been submitted to a dedicated qualification sequence. These qualification sequence were both based on the following scheme :



The Low Power SADM has been qualify through protoflight sequence on the first FM.

For Vibration and shock tests, 3 axis at qualification level have been performed.

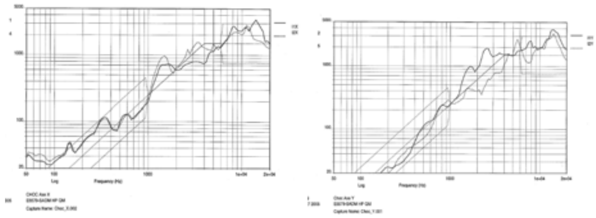


Fig. 7 : shock levels for GEO applications

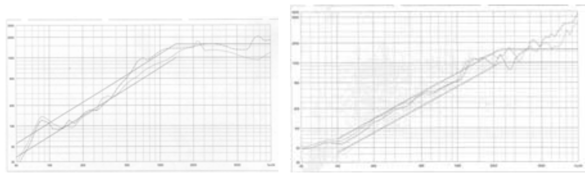


Fig. 8 : shock levels for LEO applications

The TVAC test included the thermal balances for thermal model correlation and cycling (6 thermal cycles)

The life time test were performed under vacuum in the most representative operational conditions compared to orbital ones. The number of revolutions or cycles was calculated in accordance with the ECSS E-30 Part3 Mechanisms, ie 16 000 rev at SA output.

Motorization margins have been monitored with respect to ECSS E-30 factors.

The expertise did not show any anomaly.

Fig. 9 : High Power SADM during expertise

SADM MAIN PERFORMANCES

Full step size		0.12°
Output speed		Up to 0.5°/s
Solar Array Inertia		Up to 500 $Kg.m^2$
Powered Holding Torque		8 N.m
Slip ring	Power transfer Current / Voltage	Up to 20 forward power Up to 5 return power Forward : 7.5 Amps each Return : 30 Amps each 0 to 120 V
	Signal transfers Current / Voltage	Up to 30 transfers 0.3 Amps / 120 V
	Solar Array Ground	2 redounded transfers 3.75 Amps / 120 V
	SADM Ground	1 redounded transfer 3.75 Amps / 120 V
Potentiometer	Redundancy	1 nominal cursor 1 redundant cursor
	Linearity	±0.125%
	Electrical range	356 °±1°
Reset Switch	Redundancy	1 nominal switch normally open 1 redundant normally open
	Accuracy	±0.2°
Lifetime		15 years 15000 turns qualified
Power consumption		5 W max
Total mass		Drive unit 3 Kg max Slip ring collector : 0.7 Kg to 1.48 kg max

LESSONS LEARNED :

Design :
The SADM features 5 thermal interfaces (spacecraft – conductive & radiative; solar array; connectors – spacecraft & solar array). It was consequently really challenging to identify the worst cases to be analysed and tested. The system approach is then recommended during the design phase.
More over, the stringent thermal and mechanical constraints can lead to an unfeasible design if the technical team is not in an integrated scheme. The technical manager shall insure the coherence of the worst cases identified for each field of engineering.

Components :
The use of thin section bearing brings a compact design but needs to be carefully studied because of relative stiffnesses.
Because fully qualify components for this application were hard to find, the management of the associated risk during the development phase is the key to meeting planning and cost.

At the beginning of the development, due to uncertainties on the thermal complex behaviour of the mechanism, the design was mainly driven by thermal aspects therefore constraining the mechanical analysis. The detailed analyses and the qualification results showed that thermal margin were higher than initially expected.

CONCLUSION

The SADM is a Single Point Failure for the satellite mission. Therefore the qualification sequence is all the more critical to guaranty good in flight operation. Thank to a simple design concept good performances were achieved for the SADM family
Several Fight Models are now under production.