ARCHITECTURE AND DEPLOYMENT OF A HIGH POWER SOLAR ARRAY

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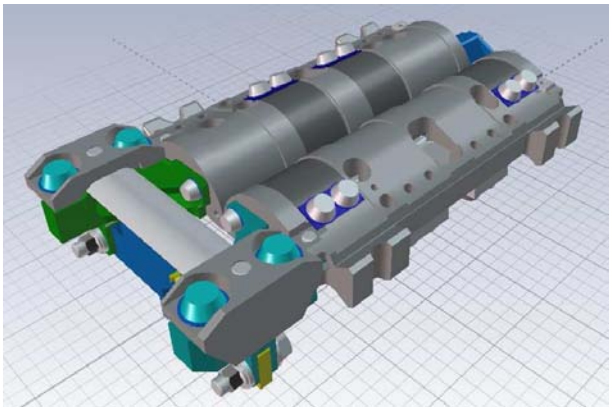
OVERVIEW

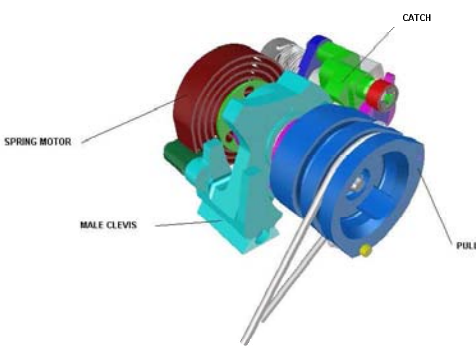
For several years, THALES ALENIA SPACE has been developping innovative mechanisms :

- frictionless hinge ADELE : two cylinders rolling on each other, motorised with a bended Carpenter Joint and latched by this unbuckled joint.
- clutching/unclutching hinge driven by mechanical cables, allowing a 180° deployment with an intermediate stop midway.

ADELE hinge

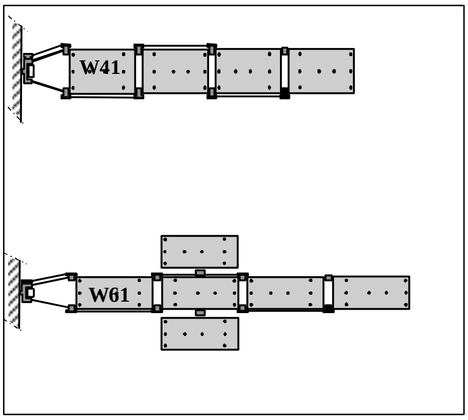


Transfer Hinge

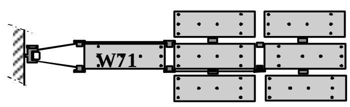


With one panel 8 m² size, multi-configuration wings have been built : 3 panels, 4 panels, 6 panels (17m long, 7m broad) , 7 panels (13 m long, 7 m broad). Up to now, 38 wings (170 panels) are flying, and more than 220 panels have been built.

Simultaneously, THALES ALENIA SPACE Cannes has elaborated associated kinematic simulators built with a commercial tool, ADAMS. A very good flight correlation of our models built with the home made tool (James) has been obtained on several SPACEBUS satellites, with SOLARBUS solar arrays including four and six panels



The correlation of this model on this rather complicated deployment (presence of two lateral panels) gave confidence to continue with the development of new design 7 panel per wing solar array :



Two specimens of this 7 panels solar array are already on orbit and flying on CIEL2 and W2A satellites. A new transfer deployment phase with 3 panels is included, based on the lateral deployment concept experienced on former Thales Alenia Space 6 panels wings, AMC23 and CHINASAT9.

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1. NEW 7 PANELS SOLARBUS SOLAR ARRAYS DEPLOYMENT PRESENTATION

1.1. Recall of classical wings deployment

The deployment includes two different phases (FIG 2):

- **partial deployment** (also called transfer deployment):
  - deployment of the transfer panel(s): unregulated deployment of one panel (FIG 1) or three panels (FIG 2) in the W71 case
- **total deployment:**
  - deployment of the in line panels (central mast) : fully synchronized and regulated deployment
  - deployment of the lateral panels if any : unregulated deployments.

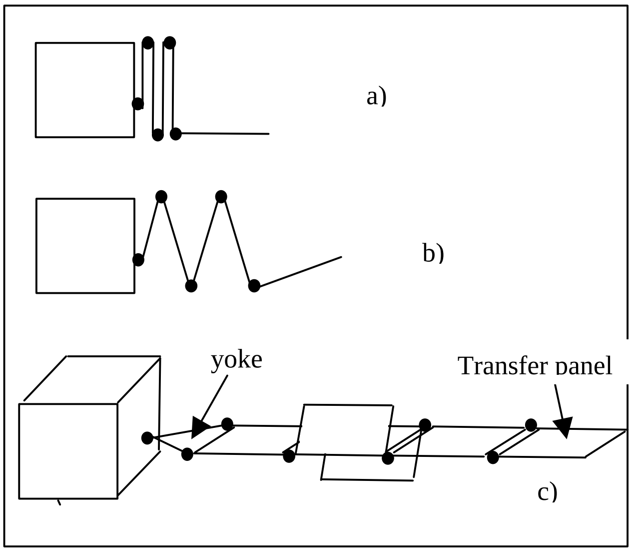


FIG 1. Deployment of a 6 panels SOLARBUS solar array
a) Partial deployment completed,
b) and c) total deployment

During the total deployment, the synchronization devices ensure a quite constant angle between the different panels of the central mast, except for satellite/yoke angle which remains twice smaller than the others (see FIG 1): the yoke rotation is 90° while the panels rotation is 180° .

Already twelve satellite with SOLARBUS solar array have been launched, with completely successful deployment of the panels :

- 2 solar arrays with three in line panels
- 8 solar arrays with four in line panels
- 2 solar array with six panels.

1.2. Deployment of a 7 panels wing

The transfer deployment is proceeded as follows : the stack of 3 transfer panels deploy of 106°. Then the first lateral panel is released and begins to deploy. When this first lateral panel is opened of more than 90°, the second lateral panel is released and deploys.

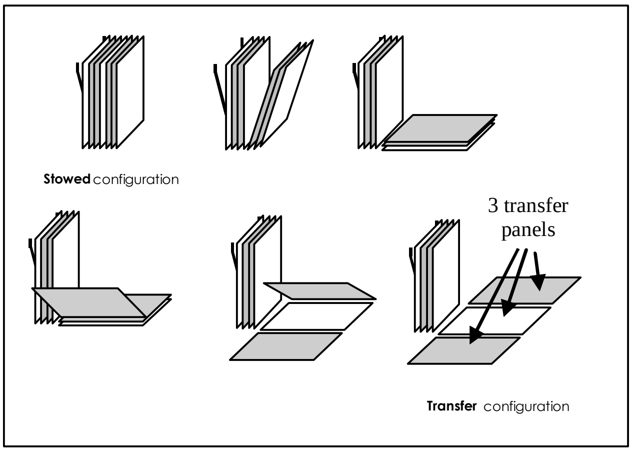


Fig 2 – 3 transfer panels deployment

The total deployment is done in the following way : the central mast is deployed. When hinges of central mast are latched at 180°, the first lateral panel is released and begins to deploy. When it reaches about 90°, the second lateral panel is released and deploys

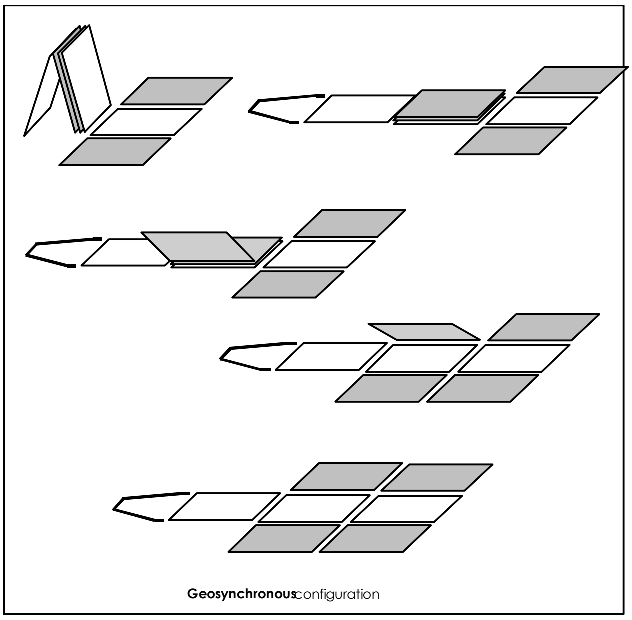


Fig 3 – total deployment

2. EVOLUTIONS NEEDED FOR A 7 PANELS WING

2.1. Transfer hinge

2.1.1. transfer hinge functioning

The transfer hinge is installed on the last outer panel interface line. The outer (or transfer) panel is interfaced through the other panel with one transfer and one standard hinge. This hinge includes a system allowing transfer opening at 90° or 106°. Indeed, for 7 panel s solar array, in order to deploy 3 panels in transfer configuration, Thales Alenia Space developed a transfer hinge with 2 aperture angle possibilities :

Transfer Hinge 90° (for a Solar Array configuration with 1 panel in transfer)

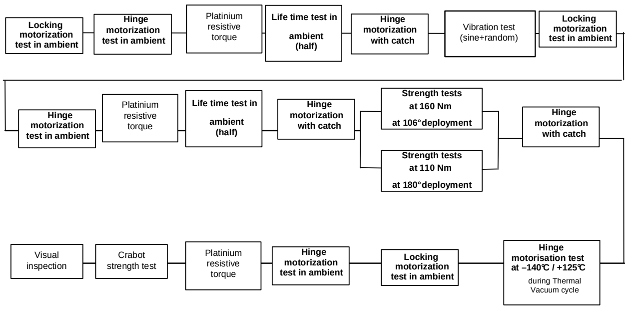
Transfer Hinge 106° (for a Solar Array configuration with 3 panels in transfer). For this last design, an angle more important to allow the opening of lateral panels was needed.

For transfer deployment, stowing points holding the transfer panels are released (and not the secondary stowing point holding all the other panels). Transfer and standard hinge motorization springs are then activated. The synchronization is unclutched by the pulley system of the transfer hinge. The transfer latching occurs at 90° o r 106° deployment thanks to the transfer pulley rotation . For complete deployment the transfer hinge is equipped of a pulley for synchronization transmission : in case of failure of the hinge line, this one can be helped by root hinge motor torque transmitted through this synchronization device. At 180°, the final latching occurs and gives to the wing its stiffness. Latching is activated when a finger fall from a cam just before end of deployment. Locking is performed through a logarithmic cam on one side and a mechanical stop on the other side avoiding hinge backlash.

Motorization of each hinge can be accurately tuned to fulfill the motorization margin requirements. These hinges have been sized to withstand the Solar Array mechanical and thermal environment. The brackets are designed to withstand the important latching shock due to large Solarbus arrays inertia, eigen frequencies and final speed. A ball joint guarantees a good behavior under mechanical loads, allows deployment (even if misalignment occurs) and provides guidance of the hinge. The hinge functional behavior is guaranteed by internal functional gaps assessed to allow deployment at any temperature of the solar array environment (no thermo elastic gap catching).

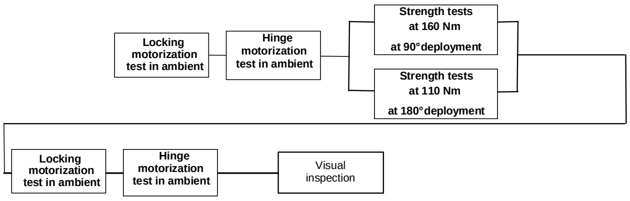
2.1.2. transfer hinge testing

Here after, the qualification test sequence for the new transfer hinge, compliant with ECSS standards :



After this test sequence, the hinge was disassembled and a visual inspection of all parts was performed.

The 90° hinge was assembled with the same parts except the 90° male clevis. In order to check the sizing of the clevis changed and the impact on the hinge, only strength tests were realized.



The performances assessed during the test sequence performed on the 106° and 90° TRANSFER HINGE permit to point out the following main conclusions :

- All functional requirements are fulfilled under the specified environment (ambient motorisation, [-140℃,+125℃] in thermal vacuum)
- The transfer hinge strength during vibrations (sine and random) and static tests is qualified,
- The lifetime is qualified for 60 cycles,
- The hinge integrity is nominal after visual inspection.

2.2. Deployment simulators

The prediction simulator done for the 7 panels configuration was designed to predict both partial and total deployment, as partial deployment is quite complicated with 3 panels aperture.

The 7 panels simulator was built with Adams. It was designed to take into account all the specificities of the components as previously for 3, 4, and 6 panels wings modelisations:

- synchronization devices effect
- root hinge regulation motor effect
- hinges precise characteristics
- harness effect.

The main issue for this deployment was the transfer phase. It was necessary to avoid any contact between transfer panels under deployment and the stack of panels still in stowed position. Indeed, the 2 lateral panels are beeing deployed while the central panel stroke is ended and the end of travel shock induces oscillations.

3. DEPLOYMENT PREDICTIONS VALIDATION

A correlation of in-flight deployment has been done on several programs with our previous deployment simulators made with James (former simulation tool). The same simulators were set up with Adams tool and reached the same correlation accuracy.

3.1. Correlation with flight deployments

Correlation between predictions from James made simulators and real flight measurements have been done on several SOLARBUS programs. All were telecommunication satellites: two of them were similar solar arrays with four in-line panels (W41), while the third one was composed of six panels (W61), four in-line panels plus two lateral panels. Very good correlation was obtained for theses three programs [1] [2].

Now, a correlation between predictions from an Adams made simulator and real flight measurements is being done on a 7 panels SOLARBUS solar array.

3.1.1. Correlation method

The flight deployment data have demonstrated a great similarity between North and South wings deployment. South wing deployment was chosen to be correlated.

Two kind of parameters had to be defined in order to simulate the deployment :

- solar array parameters: hinge characteristics, synchronisation stiffness and damping, …
- electrical motor parameters: torque sensitivity, internal losses, efficiency, wiring resistance.

a) Solar array parameters

Solar array parameters, which were known with a slight incertitude through components acceptance tests and which are known to be slightly dependent of temperature, were adjusted to fit the flight curves.

b) Electrical motor parameters

The deployment motor parameters (torque sensitivity, resistive torque, efficiency) can be calculated exclusively from the flight data (motor torque, current, voltage, and speed).

From these set of parameters, it was possible to perform correlations with flight data of South wing deployment.

3.1.2. Motor torque

The following curves (FIG 5) stand for the measured and simulated motor torque. The simulation begins exactly when the pyro has been fired.

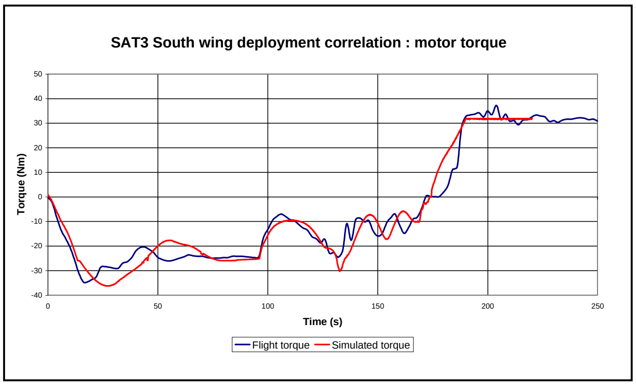


FIG 4. Measured and predicted motor torque

The correlation is quite accurate and put into evidence the different phases of the deployment :

- The wing's release is just followed by an active braking of the motor which acts as a generator (between 20 and 30 s).
- Then the wing stabilises under the friction torque of the regulator, until time = 96 s.
- At 96 s, the motor is powered ON, allowing thus a release of the wing that can pursue its deployment.
- The wing acceleration necessitates a strong active braking of the regulator (around 130 s), generating some oscillations after.
- The motor ends the deployment by applying a positive motor torque that facilitates the hinges latching (after 180 s).

3.1.3. Motor current

The following curves (FIG 6) stand for the measured and simulated motor current.

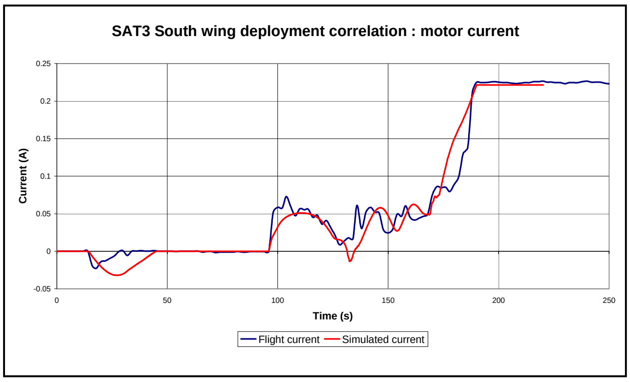


FIG 5. Measured and predicted motor current

Here again, the correlation is quite accurate.

3.1.4. Motor voltage

The following curves (FIG 6) stand for the measured and simulated motor voltage.

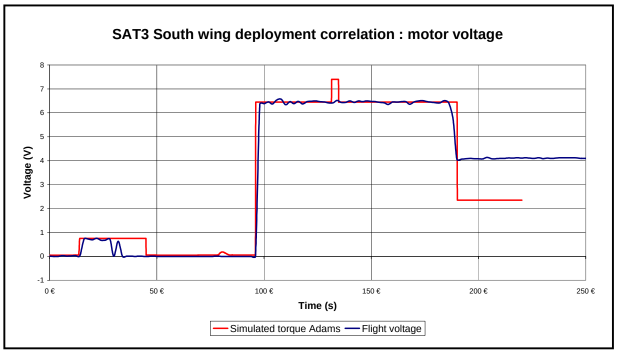


FIG 6. Measured and predicted motor voltage

It can be noted that the simulation predicts longer dissipation phases than the real ones seen during the flight deployment.

3.1.5. Wing total current

The following curves (FIG 7) stand for the measured and simulated current generated by the cells of the wing.

The correlation is very accurate until the lateral panels latch and induce a global wing rotation. Indeed, when lateral panels latch, the torsion torque generates a global rotation of the wing and therefore a current decrease. The wing rotation is only braked by the solar array drive mechanism internal friction torque, because this mechanism is in OFF mode. So, this correlation shows that our model of the solar array drive mechanism behaviour could be enhanced.

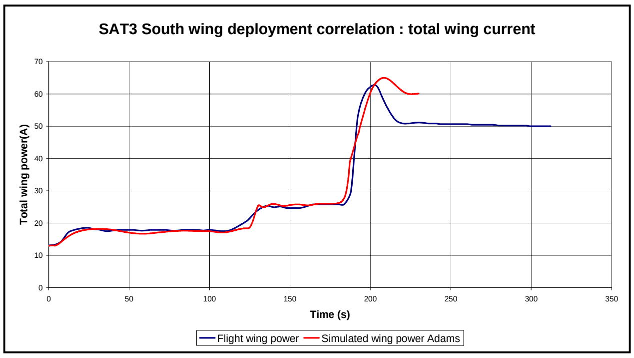


FIG 7. Measured and predicted wing total current

3.1.6. Deployment correlation of 7 panels wing deployment

The correlations of in-flight deployments on CIEL2 is good, and is undergoing for W2A program. The first results show a good quality of correlation on the motor parameters.

4. CONCLUSION

Thales Alenia Space has been developing for 30 years innovative mechanisms such as a frictionless hinge and a transfer hinge including in one mechanism 5 different functions. Associated to a deployment prediction capability based on in-flight correlated simulators, it has been possible to elaborate a new generation of solar arrays: 7 panels per wing, 3 in-line and 4 lateral panels. That allowed to obtain an increased power during the transfer phase owing to the deployment of 3 panels, 1 in-line and 2 lareral ones.

The transfer hinge mechanism has been successfully adapted to the new requirements coming from this new transfer deployment. Its reliability was increased and better performances were proven through a qualification test sequence.

A very good correlation of deployment tools predictions has been obtained on several satellites of the SPACEBUS family already launched. These satellites included four in line panels solar arrays and four in-line plus two lateral panels solar arrays, with regulated and synchronized motion. Flight data as regulation motor parameters and wing current have allowed to correlate the deployment dynamic predictions of these three programs with a good accuracy. Motor torque, current and voltage, total wing current have been correctly correlated, showing that the regulation system has been efficient and well predicted.

The correlation of this tool for a 7 panels wing on CIEL2 in-flight deployment gives good results.

5. REFERENCES

[1] Innovative light weight mechanical architecture with thin lateral panels deployed with shape memory alloy regulator, L. D'Abrigeon, A. Carpine, 7th European Space Power Conference, Stresa, May 2005

[2] Deployment analysis of very large advanced structures for solar arrays and model correlation, A. Carpine, G. Ladurée, 23rd ICSSC, Rome, September 2005