THE CHALLENGE TO REBUILD CRYOSAT

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ABSTRACT

Getting a second chance is always a challenge. The programmatic support for CryoSat-2 had to be established first and then the entire project had to be set-up again.

This paper concentrates on one side on the aspects of resource availability, change implementation and very tight schedule for CryoSat-2 and on the other side to perform very carefully all the satellite validation once again respecting the lessons learnt from the first build.

The right balance between it’s “only a rebuild” and the full awareness of the consequences of implemented changes had to be established through out the project CryoSat-2.

1. CRYOSAT-2 SYSTEM ASPECTS

After the loss of CryoSat due to a launcher failure October 8th 2005 the wish to “rebuild” the satellite was expressed immediately. The RfQ was sent out begin December 2005 already. The final decision for the CryoSat-2 rebuild took place February 24th 2006.

For Astrium as prime contractor the major challenges on CryoSat-2 were or even are:

− To build up the new project team at Astrium, as this project was not planned and CryoSat personnel was already committed to work in other projects.
− To get the commitment of the CryoSat consortium to provide the equipment again or to find quickly alternative suppliers.
− To implement changes / improvements as requested by the new statement of work or by the lessons learnt from CryoSat-1.
− And finally to do all that in the shortest possible time.

1.1. Project Team Build-up

Already during the final preparation for the CryoSat launch some project team members where committed to work for other projects. At this point in time it was planned to make use of the CryoSat experiences for SWARM by transferring the personnel to this project. Even the project manager was assigned to work for SWARM. With the decision to rebuild CryoSat it was essential for both projects to split the team experiences such that key knowledge was available for both.

For each key discipline a CryoSat team member could be made available also for CryoSat-2; such the continuity for the project can be granted. The proposal team did start with 12 people and was subsequently increased after the CryoSat-2 contract agreement. Meanwhile the team is already supported by check-out and AIT personnel. New colleagues have to get sufficient time to learn all about CryoSat. The early training for the final integration of the satellite is a key feature to make sure that assembly, integration and the final testing of CryoSat-2 can be performed reliable and fast.

Positive draw-back of the new team members is their accuracy and carefulness, while “old” team members may be affected by “deja-vu” events that may result in low attention to possible critical situations. The combination of experienced CS-1 members and new team is a success factor for CryoSat-2 and thus the project is running smoothly.

1.2. CryoSat-2 Consortium Establishment

In expectation of the RfQ Astrium contacted all former CryoSat companies introducing the possible rebuild of the satellite under the schedule and budget constraints known at that time. Most of the companies responded that they have resources available to perform the rebuild. Some however indicated already that the “old equipment” is no longer the preferred delivery due to further design evolution or because of communality with other projects.
Other companies have not only changed their names but have been restructured in addition. Two of them had to make sure that the experienced people – which left the company meanwhile – committed their support to the project under separate contract.

There was only one item requiring an open competition process to find a new suitable supplier because the company had the product not longer in its portfolio.

Only six months after the CryoSat disaster Astrium placed the first contract for CryoSat-2. For the others the sequence of contract negotiations was staggered according to the expected lead times and the need dates for the planned AIT sequence.

To get sufficient attention also by the higher management of the companies most of the contracts have been place with a penalty scheme and incentives for in time or even advanced delivery. After one year in the project we can state that most of the equipment will be delivered in time even for those we have experienced major NCRs meanwhile. Only two candidates are suffering short comings in engineering availability due to other projects and have announced some delay.

This shows that “incentive” is an important parameter for the project.

1.3 Change Implementation

In CryoSat-2 changes have been introduced. By the SoW a fully redundant Siral instrument was required.

To achieve a fully symmetric configuration of the two Siral instruments (which is required for performance reasons) the EPC (light green box in Figure 1) was moved to the up right corner. The second set of electronic boxes was then accommodated in mirrored position on the plate as given in Figure 2.

In-between the instrument boxes the additional waveguides, couplers and the waveguide switches (necessary to connect both instruments to both antennas) are accommodated in a way that the length up to the antenna horns is identical.

This redundant instrument configuration requires two different radar data bases and result in slightly different instrument performance.

Further fully redundant interfaces between units and a longer life time of 5.5 years was requested by the SoW. During the negotiations with the DORIS instrument supplier it was finally decided to go with the next generation Instrument the DGXX, providing slightly improved performance.

From the operational people several SW changes have been requested to improve routine satellite operations:

- Extended monitoring also of AOCS parameters
- Extended capabilities to switch redundant units
- Easier upload of command sequences as mission time line

From the lessons learnt some 10 smaller changes have been implemented to cover deficiencies encountered in different areas during the CryoSat build.

Other changes had to be introduced on all levels as after 5 years some parts became obsolete, especially in the RF sections.

Also the EGSE was an issue, because some of the components will be 10 years old at CryoSat-2 launch. The workstations and PCs are outdated including the SW running on these systems. For some of them SW maintenance is no longer available. In consequence the EGSE for CryoSat-2 was upgraded. The key feature for this upgrade was to make sure that all test and evaluation SW and the test data base developed for CryoSat-1 could be migrated on the new system for further use.
We have not counted all the changes implemented so far for the build of CryoSat-2. The major changes have already been mentioned but there is a very high number of changes which are not so obvious:

- Foot prints of boxes have changed
- Different harness to cope with changed equipment and extended cross coupling
- Position of balance masses are new due to second Siral instrument
- Extended cross coupling is implemented and needs to be fully verified
- Heater and control circuits have different settings
- SW functionality is extended which needs extra testing
- And, and, and

Only some of the equipment - already recurring for CryoSat-1 - as the Tank and the Magnetometer and small mounting parts are fully reused on CryoSat-2.

The build of CryoSat-2 is based on a very solid knowledge which is of the advantage because a lot of plans, analyses and procedures are available but due to the amount of changes all the details in the documentation have to be checked very carefully if they are valid for the new configuration as well.

The big challenge during the proposal preparation – of only 2 months - was to make sure that all the changes were well covered in the updated specifications and ICDs especially for the equipment where we had to use the next generation equipment. A quick run through all major configuration aspects and system analyses had to make sure that no further system adaptation was required by all introduce changes.

Even before and then in parallel to above activities obsolete parts and all long lead items had to be identified and its procurement had to be initiated to avoid delays in the production. This was covered by an advanced budget and started in November 2005 already.

The successful equipment qualification reviews (some 15 of them in approximately have a year) and the system delta CDR demonstrated that the overall system configuration and functionality is consistent. This review was concluded only 9 months after start of the project.

### 1.4 Schedule Aspects

To secure the functionality and quality of CryoSat-2 it was decided during the proposal preparation to run the full test and verification program as for CryoSat-1. As a consequence roughly one year is required to perform all the necessary activities. This decision was driving the need dates for the equipment delivery and the start of the integration. It ended up in a very tide schedule for our subcontractors (only 22 months for the redundant Siral).

Also in a second build one can expect problems during the manufacturing and testing of the equipment which need additional activities on subcontractor level and on prime level.

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![Figure 3. Base line schedule CryoSat-2](image-url)
Therefore the planning was limiting the dependencies wrt the integration and test sequence to the absolute minimum providing flexibility to change the sequence.

For CryoSat-2 there is no time to perform any electrical or functional dry run testing after delivery and prior to the integration onto the satellite. This requires a perfect preparation of all procedures to make sure that all prerequisites for the integration and tests are in place. As functional integration is using onboard SW and additional test SW the interaction between those has to be proven well in advance to avoid any delay caused by unexpected behaviour. The early and solid preparation of all satellite testing using the Real Time Test Bed (RTB) and the simulators to debug the test sessions is a key element to secure the AIT schedule.

From project approval until Launch of CryoSat-2 only 3 years are allocated. The very detailed and flexible planning including some contingency times has paid off up to now. The delivery delays announced by some of the subcontractors could be compensated and the challenging schedule can be met.

1.5 Status of the CryoSat-2 Satellite build

The CryoSat-2 structure was delivered as contractual agreed begin March 2006 just one year after the project kick-off. The mechanical integration has started now and is running as planned.

The upgraded EGSE is available since begin of 2006, the modified CDMU (satellite core computer) engineering model has been delivered mid March and integration in the Real Time Test Bed (RTB) has started. Further the first updated SW version is available since begin of March. This SW was successfully loaded and executed in the simulator environment. The preparations for the satellite functional integration are running already.

Up to now delays in the delivery announced could be compensated by rearrangement of the integration activities with only minor impact on system level.

The CryoSat-2 build is well on track.
2. SIRAL-2 INSTRUMENT ASPECTS

In the frame of the CryoSat-2 project the development of the SAR Interferometer Radar Altimeter (SIRAL-2) commenced in March 2006 in Thales Alenia Space following the approved procurement of the CryoSat-2 mission funded by ESA. To improve overall mission reliability SIRAL-2 accommodates two radars in cold redundancy whilst sharing the same interferometric antennas. The most challenging features driving the design are high instrument stability and tracker robustness.

CryoSat-2’s mission objectives remain the same. CryoSat will measure, via estimates of surface elevation, rates of change of ice thickness on both land and sea very precisely to reduce uncertainties in the knowledge of the trend towards diminishing polar ice cover. This will improve our understanding of the relationship between ice and global climate.

The high performance of SIRAL can be resumed as follows:
Siral-2 is 3 altimeters in one. It includes three main different modes:
- The conventional pulse limited measurement mode for interior land ice sheets and sea called : Low Resolution Mode
- The high along track resolution mode for sea ice called: SAR (Synthetic Aperture Radar)
- The high across track resolution mode for ice sheets margin: SAR Interferometric.

The associated performance obtained on the former SIRAL are summarized hereafter:

<table>
<thead>
<tr>
<th>Instrument Mode / Performance</th>
<th>INSTRUMENT CONSTRAINTS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Low Resolution</strong></td>
<td></td>
</tr>
<tr>
<td>Altitude accuracy &lt; 2 cm</td>
<td>Delay : bias ≤ 100 ps variable ≤ 50 ps Amplitude stability &lt; 0.5 dB</td>
</tr>
<tr>
<td><strong>High Resolution</strong></td>
<td></td>
</tr>
<tr>
<td>250 m in along track</td>
<td>SAR =&gt; Coherent instrument Burst amplitude variation &lt; 0.5 dB</td>
</tr>
<tr>
<td><strong>High Resolution Interferometry</strong></td>
<td>Antennas &lt; 15 arcsec Electronic &lt; 10 arcsec</td>
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To reach these results the behaviour of each component is characterized, all parameters are tuned, as every measurement accuracy contributes to the final budget and makes each instrument unique.

The challenge to rebuild SIRAL begins with the high performance and how to reach them.

First step is constrained by the components availability and obsolescence.
- The support of space industry as in Alcatel Alenia Space is essential to benefit of volume of components used on several space program. The reuse also of developments for several space applications implies to maintain the product available even 6 years after its first use. This is the way we proceed and allow us to build a new SIRAL even if technology’s evolutions have a turn cycle of 3 years.
- The component obsolescence replacement is therefore minimum and coupled with minimum evolutions (former non conformance accepted, little software improvement), compatibility during assembly guaranties the reuse of long duration tuning procedure applied on first SIRAL model.

Second step is the availability of key people.

The knowledge acquired during 4 years of design and development is essential to the success of the quick start given to build the new instrument. The maximum reuse and the easiness to exchange information inside and outside the project authorized us to begin the manufacturing in less than one month with all files ready and very little modification included. All Equipment Qualification Status Review were closed in less than 3 months.

Third step is given by the motivation associated to the mission goal.

SIRAL is the main instrument of CryoSat for the “Earth Explorer Opportunity Mission”. In favour of its high performance that no other altimeter reached, it will reveal new behaviour on ice sheets but also on coastal zones, water inland and other types of terrain. It will “explore” and everybody in the project is still motivated to have a look on what will be its capabilities in flight. In the case of CryoSat 2, the quick decision to rebuild the satellite kept the motivation and was perceived as gratitude of the work well done - this is essential.

Currently all modules of the instrument are in development prior to final integration on the platform in 2008 and an expected CryoSat-2 launch in 2009. The next several months will be dedicated to intensive testing which will give a detailed insight of the instrument performance and capabilities, essential for the success of the mission.