Engineering TEAMSAT — From Concept to Delivery

A. Bradford, F. Müller-Stute & B. Sarti
ESA Directorate for Technical and Operational Support, ESTEC, Noordwijk, The Netherlands

The role of the ESTEC Engineering Section in the design and manufacture of TEAMSAT grew from the design phase, when only a few individuals were involved, to the manufacture and assembly phase, when almost all of the staff in the Section became involved in the project.

Designing TEAMSAT

In the early phases of the TEAMSAT project, much of the mechanical and spacecraft configuration design work was carried out by two Young Graduate Trainees (YGTs) working in ESTEC's Mechanical Design Office and Structural Design Section (A. Bradford and A. Hedqvist)

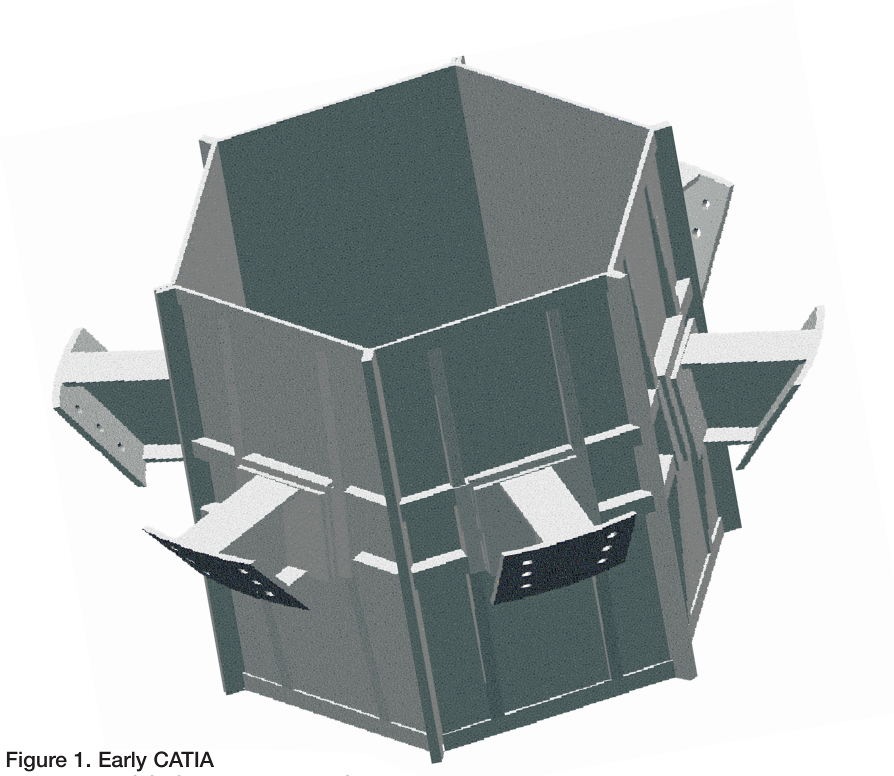

Figure 1. Early CATIA concept model of a cone-mounted option for the TEAMSAT box

The TEAMSAT Structural Model (StM) and Proto-Flight Model (PFM) – along with the Maqsat-H structure, for representation of the TEAMSAT mechanical interfaces – were entirely modelled using the CATIA 3D facility. The resulting 'Master Model' rapidly became a source of reference for most of the sub-system designers and project representatives.

A very early system concept is shown in Figure 1. In this design, the TEAMSAT box is a hexagon, the original concept before internal volumetric requirements demanded a change to an octagonal shape. The method of attachment to Maqsat-H shown is also an early concept, since at this stage attachment of TEAMSAT via the lower cone was being considered.

Detailed information on all of the existing components (e.g. transponders, batteries, and TEAM experiment master units) was gathered to form a kind of central archive. Such information was obviously vital to ensure that the CATIA model was updated with the correct mass and dimensional data for all the components that were to make up the internal design of the spacecraft. Additionally, new components were first checked against the Master Model in order to define a volume envelope and a possible location in the spacecraft. Further examples of the advantages of building and maintaining an accurate 3D model of the complete spacecraft are as follows:

– The spacecraft rapidly became a very complicated system and it was important to model the system in three dimensions to ensure that all components would fit correctly.
– Vital simulations of the separation of the two elements of the YES sub-satellite were

possible using the model. This ensured that changes and modifications would not compromise the fact that YES would be able to eject without damaging either of the two systems.
- The CATIA 3D software was extensively used to manipulate the spacecraft configuration to ensure that the mass properties of the system remained favourable, i.e. within the Ariane-5 given limits, as new items were added to the internal configuration. This software automatically calculated mass properties (centre of mass, mass moments of inertia and principal axes of inertia) for the system model. The mass properties defined and calculated for the PFM ensured that these could be matched when designing the 'Dummy' (Structural Model).
- For the design of new components, especially at system level (e.g. OBDH boxes, PC104 computer unit), the CATIA software facilitated 'automatic derivation' of the detailed engineering drawings directly from the 3D model.

Figures 2 — 4 show the CATIA 3D Master Model of the system as well as a sub-system assembly drawing generated directly from the model.

Manufacture and testing of TEAMSAT

Due to the incredibly tight schedule for the project, the design phase rapidly began to overlap with the manufacturing phase. Manufacture and testing of the Dummy was required before the configuration of the PFM was even finalised. At this point, the involvement of the Engineering Section increased dramatically. Although the manufacture of the primary structure (octagonal box, cover and lid) for both the Dummy and the PFM was contracted out, there was still significant preparation work to do at ESTEC. The Mechanical Workshop staff was charged with the manufacture of approximately 230 kg of dummy masses, which were low cost, but mechanically fully represented the spacecraft. As was the case with the project as a whole, the work was required very quickly and the experience of the workshop technicians was evident as time constraints were met. The staff's enthusiasm throughout the project was reflected by their willingness to work long hours (often evenings and weekends) to get the job done on time.

While manufacture/assembly of the Dummy was still in progress, work had already begun on the building of custom-designed flight model components with, once again, Engineering Section involvement (Fig. 5). As

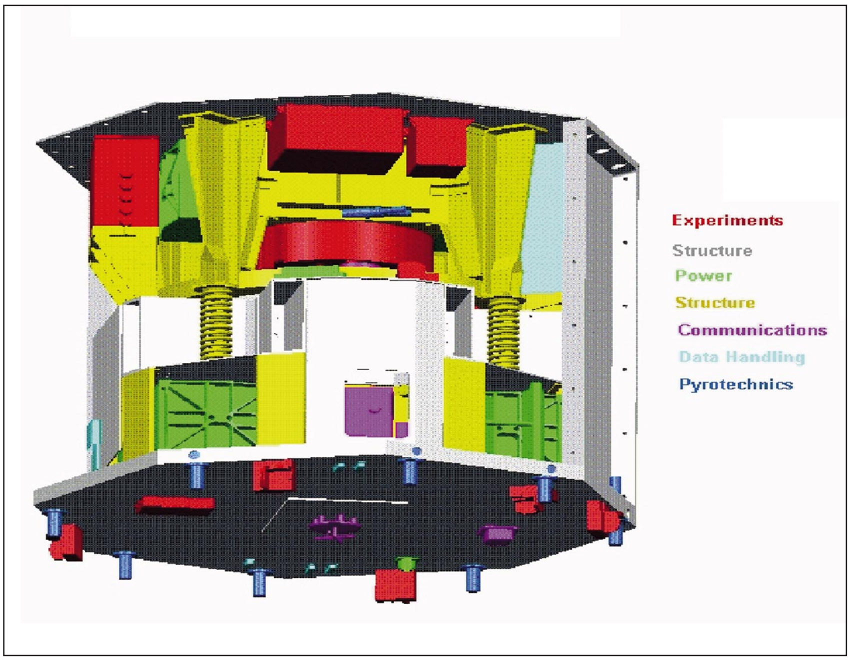

Figure 2. Final CATIA Master Model of the TEAMSAT system, colour coded to identify sub-system groups

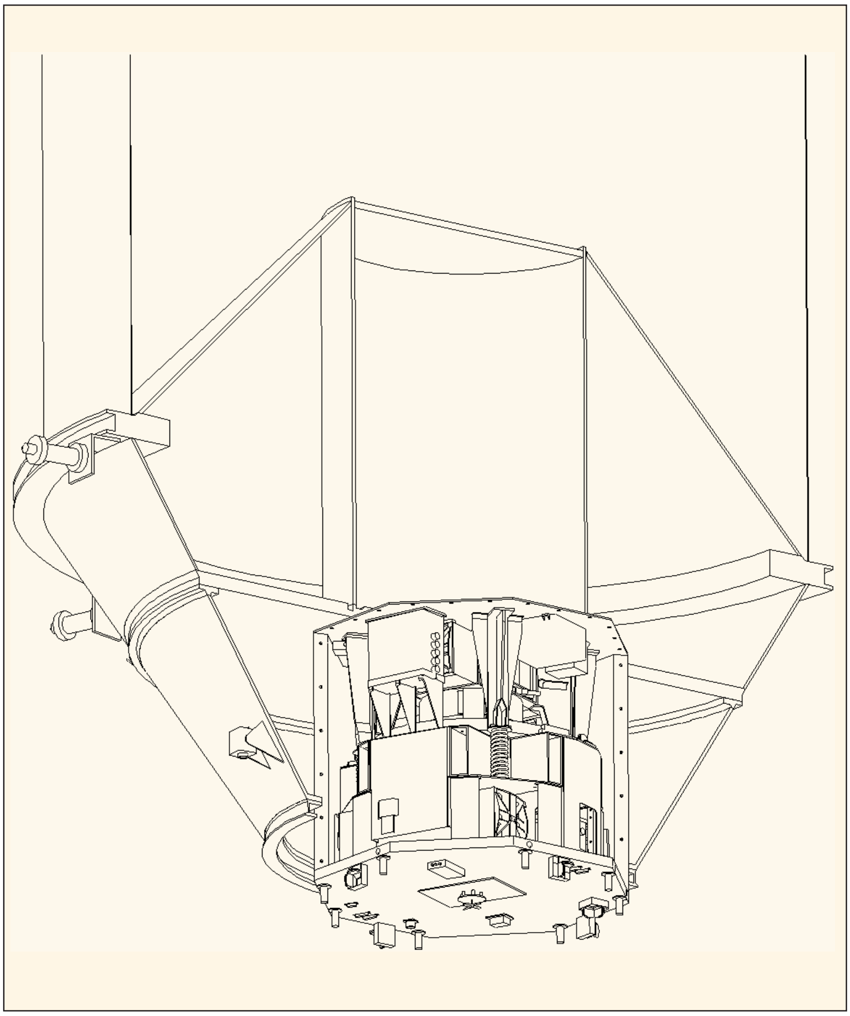

Figure 3. Cutaway view (CATIA model) of TEAMSAT mounted in Maqsat-H, including TEAMSAT cone-mounted sensors

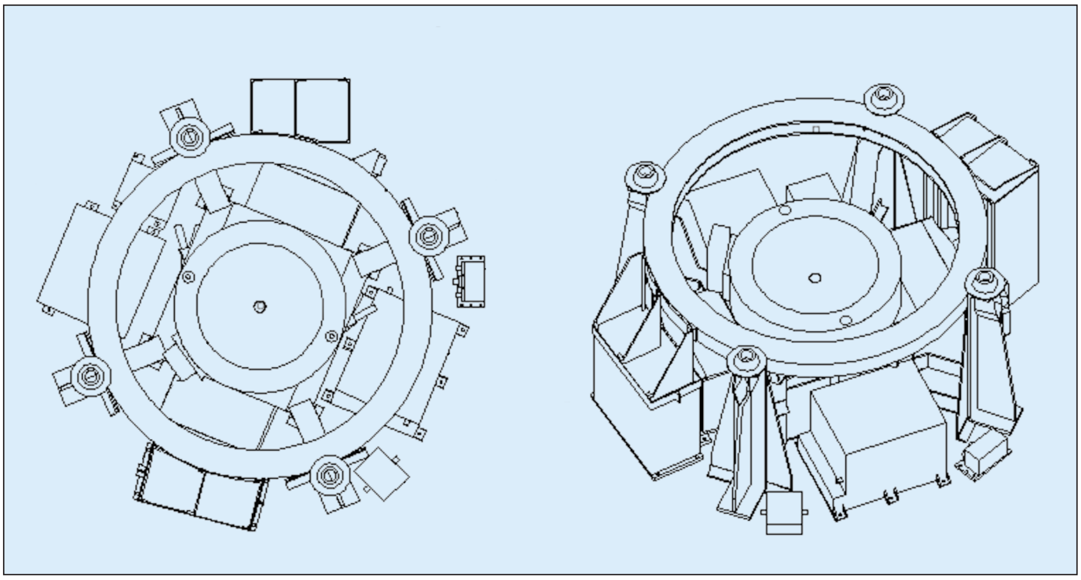

Figure 4. Production assembly drawing of the TEAM sub-system, generated from the CATIA system Master Model

Contribution of the ESTEC Engineering Section

Mechanical Design
– all primary & secondary structure elements (StM & PFM)
– internal configuration & layout
– OBDH mechanical enclosures
– PC104 computer unit mechanical enclosure
– 'JORIS' flight computer mechanical enclosure
– MGSE & test support hardware.

Mechanical Manufacture/ Production
– TEAM and YES structural support elements, including complete manufacture of TEAM and YES secondary structure and ejection system support structure (mainly rivetted and welded sheet-metal elements)
– manufacture of dummy masses for Structural Model
– significant modifications to spacecraft primary structure (to meet ever increasing fixation/ support requirements)
– production of aluminium machined enclosures for two complete OBDH units, 'JORIS' flight computer, JANE power conversion unit, two 'Quick Cam' units
– production of over 50 small machined and turned parts, including ejector system components, pyrotechnic catchment devices
– production of many support platforms for sensors, including solar aspect sensors and GPS antennas
– various MGSE elements

Electrical Manufacture/ Production
– manufacture of complete flight harness for spacecraft
– flight-qualified soldering of PCB boards & components for two OBDH units (two boards per unit), JORIS flight computer, JANE power conversion unit, solar aspect Sensors
– refurbishment/ manufacture of GPS antennas and LNA assembly
– manufacture of various semi-rigid RF cables.

It can be seen from this list that many of the manufactured elements were produced with input from both the Mechanical and Electrical Workshops, as the Engineering Section worked to produce complete components, manufacturing both the metal enclosure and the electronic elements.

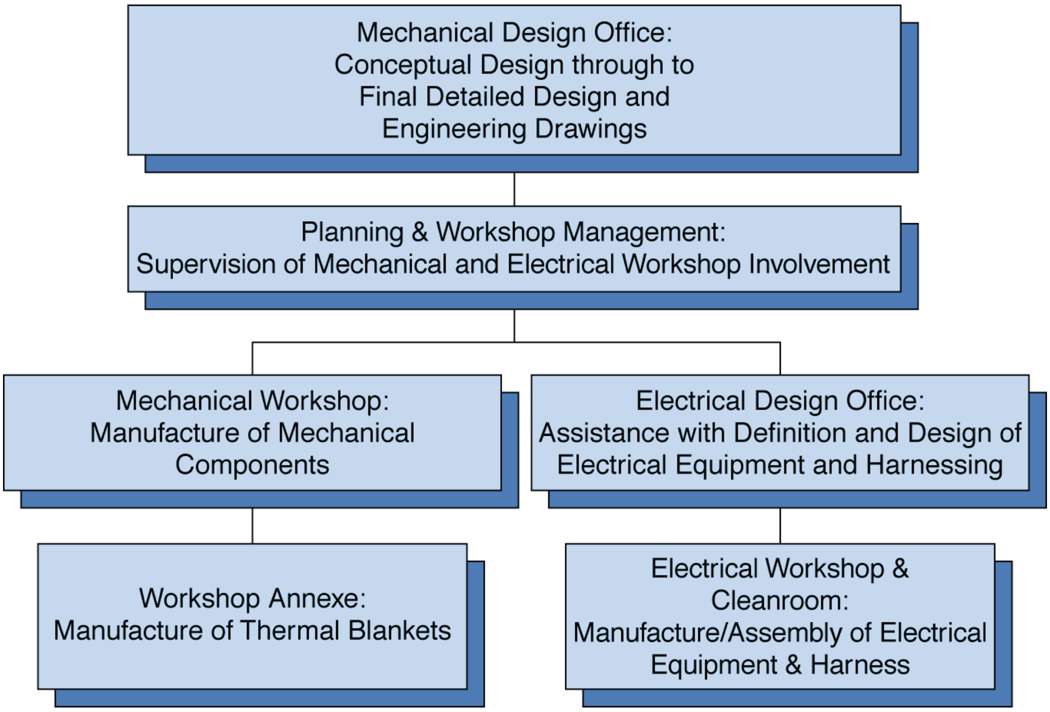

Figure 5. Progressive involvement of the Engineering Section in TEAMSAT

time went on, the estimate of required workshop support increased and the manufacture of the PFM became a major Engineering Section effort. The Electrical Workshop became involved during the manufacture of the printed circuit boards (PCBs) for the on-board computers, data-handling systems and other small electrical devices. The Mechanical Workshop began work on the secondary structural elements, and the manufacture of various boxes and enclosures for the many custom-built electrical devices included in the spacecraft.

The Mechanical Workshop consisted only of ESA staff. The Electrical Workshop, however, required additional outside help to support the large number of tasks entrusted to it. This was particularly the case for the manufacture of the harness. One ESA staff member was even persuaded to come out of retirement to help supervise the production of the harness. The remainder of the harness work was done by three stagiaires, recruited especially for the project. These three young engineers were given a truly ‘hands on’ training experience whilst producing the flight-qualified harness. As the harness was readied for integration on the spacecraft, two of the three stagiaires began to concentrate more on the spacecraft itself, housed in the Erasmus Building High Bay at ESTEC.

Throughout the manufacturing and assembly phases of the project, there was close cooperation between the Design Offices and the Workshops. With time constraints as tight as they were, this cooperation was vital. It was also helpful that the areas were in the same vicinity, which fostered easier access and face-to-face discussions concerning engineering drawing details or the resolution of technical discrepancies.

This interface was sometimes stretched to the limit. Situations arose several times in which a component was required very quickly, often before a completed engineering drawing could be provided. In these cases, the Design Office would release a preliminary drawing with only the overall exterior dimensions. Once manufacturing of the component was started, more detailed drawings were provided in time for the Workshop staff to complete the task. This approach may not have been ideal, but it did ensure that optimum use was made of all resources.

Conclusions

This unique project showed how productive close co-operation between the different disciplines represented in the ESTEC Engineering Section can be.

The on-site design and manufacturing capabilities provided an essential contribution to the success of TEAMSAT.