The ESA Project Office Cost Model

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The manpower dedicated to Management, Product Assurance and Engineering of a project, is a significant slice of the total cost and can be more than 20%. Moreover this ratio can even further increase considering the actual cost at completion of a mission, since in case of schedule overrun this area is majorly affected by cost growth.

Price negotiations between Space Agencies and Industrial Contractors for this part of the work is also one of the most difficult topic, due to the complexity and uncertainty in quantifying the resources in terms of manpower required per type of design activity.

Within the European Space Agency (ESA) this specific group of activities is known as Project Office.

This paper describes the definition and the implementation of a Project Office parametric cost model for Space Segment aimed at producing an independent cost and schedule estimate of Industrial teams manpower allocation to set up budget, target pricing and later support price negotiations.. In particular the model focuses on Project Office cost for all the main industrial actors involved in the design and development of a satellite taking into account the possibility of heavy industrial set-ups with significant overlaps frequently observed in the European institutional environment but also to provide reliable estimates about lighter team structures thus allowing quantified trade-offs between various types of organization.

From the analysis of a wide database of past and present missions of ESA, two main levels have been studied.

First level considers the Management, Product Assurance and Engineering for System, Platform and Payloads. It is based on a “team size” definition: : an average team size through the whole duration of the project is estimated , on the basis of several characterising factors such as the industrial consortium complexity, the size and number of payloads, and the expected quality level .

The second level concerns the subsystems engineering manpower estimation and is based on parametric models that link the technical characteristics of the subsystems with the total effort required to design them, in terms of absolute number of hours.

This paper describes the steps andlevels of the model development.

I. Introduction

Dealing with space projects cost estimate, in the early phases the manpower cost, due to the uncertainty of the complexity and duration of the related activity, represents often a challenge for the cost estimator. Moreover, European Institutional space project shows often a heavy industrial set-up which leads to an even more complicated case due to the necessity to involve contractors from the various participating Member State in a fair basis with respect to their financial contribution.

Management, Product Assurance and Engineering costs can be identified at each level of the project: from the global satellite system level down to equipment level. During the early phases of the project[4], the Project Office (PO) cost is usually estimated and detailed at System level only for the Satellite and the related Platform and Payloads. The engineering activities for the Platform and the Payload are in general broken down for the different engineering domains (e.g. Mechanical, Electrical, AOCS, etc.). The subsystems engineering is characterized by these engineering disciplines.

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The ESA-ESTEC Cost Engineering Team has developed and is further improving an Excel-based model for cost estimates for Space Projects. It provides cost estimates with a breakdown of Management, Product Assurance and Engineering activities at Satellite, Platform, Platform Subsystems and Payloads level, taking into account also the contractual framework of the project.

II. Subsystem PO cost estimate

A satellite platform design is made of several interdependent subsystems. The PO cost model estimates the PO cost of the following:

1) AOCS (Attitude and Orbit Control Subsystem);
2) Propulsion;
3) Electrical Power;
4) TT&C (Tracking, Telemetry and Control);
5) Data Handling;
6) Structure and Mechanisms;
7) Thermal Control.

Considering the engineering, the definition of a number of hours that characterizes the effort required for a certain subsystem design leads to an equation that is independent from the project schedule and the company rates, but is related only to the technical characteristics of the subsystem under consideration.

These technical characteristics are represented by a variable defined within the ESA Cost Engineering Team called “RACE complexity” (Ref.2) which is based on a common scale among ESA Cost Engineering tools and is defined ad hoc for each subsystem by qualitative technical and programmatic characteristics.

Figure 1 shows an example of Total Design Hours in relationships to the Subsystem Complexity: The design Hours have been normalized with respect to various parameters (e.g. Design maturity, Subcontractor responsibility, etc.)

This approach allowed the definition of a monovariate equation:

$$Normalized\ Total\ Engineering\ Hours_{j=} f(Complexity_j)$$

Where j is the j-th Platform subsystem.

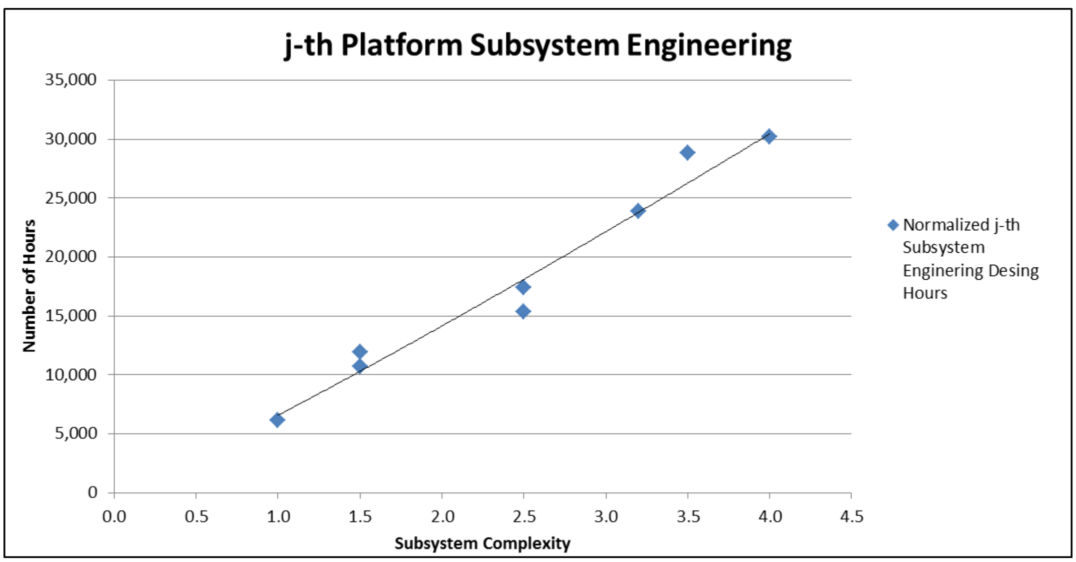

Figure 1. Example of a Platform Subsystem Engineering Design Effort VS Complexity.

On these equations specific CERs have been developed ,which estimate the cost of the subsystems engineering starting from the required engineering hours, through the company hourly rates, taking into account also additional parameters such us the S/s industrial set-up. The hourly rates, for Mgmt., PA and Engineering, used by the model, are defined according to the size of the company, which is an input of the model. These average rates have been defined on the basis of the actual companies ones and are all-inclusive .

The Management and PA hours are based on proportion averages to the Engineering effortand defined for each subsystem.

This approach leads to results that, in terms of cost and man-hours, arebased on an optimum satellite schedule. This approach is valid assuming that the engineering resources are allocated at subsystem level on the basis of the schedule critical path: i.e. the team size for the subsystem engineering is derived spreading the required hours over the platform schedule.

III. System PO cost estimate

"System" may be referred to the satellite (Sat), to the platform (PF) and to the payload (PL). The system PO costs represent those Mgmt, PA and System Engineering activities which are schedule driven and assumed as characterized by a fixed team size during the Sat, PF or PL schedule.

Based on regression analyscovering several space projects and programs, system manpower data, team sizes ranges and the related drivers for each PO subject for Sat, PF and PL. have been determined.

Figure 2 shows as an example the typical ranges calculated for Mgmt and PA team size at platform level. From this graph it is also possible to see how a simple direct relation with the mass (which is one of the most common independent variables in space born cost models), cannot be established in our case.

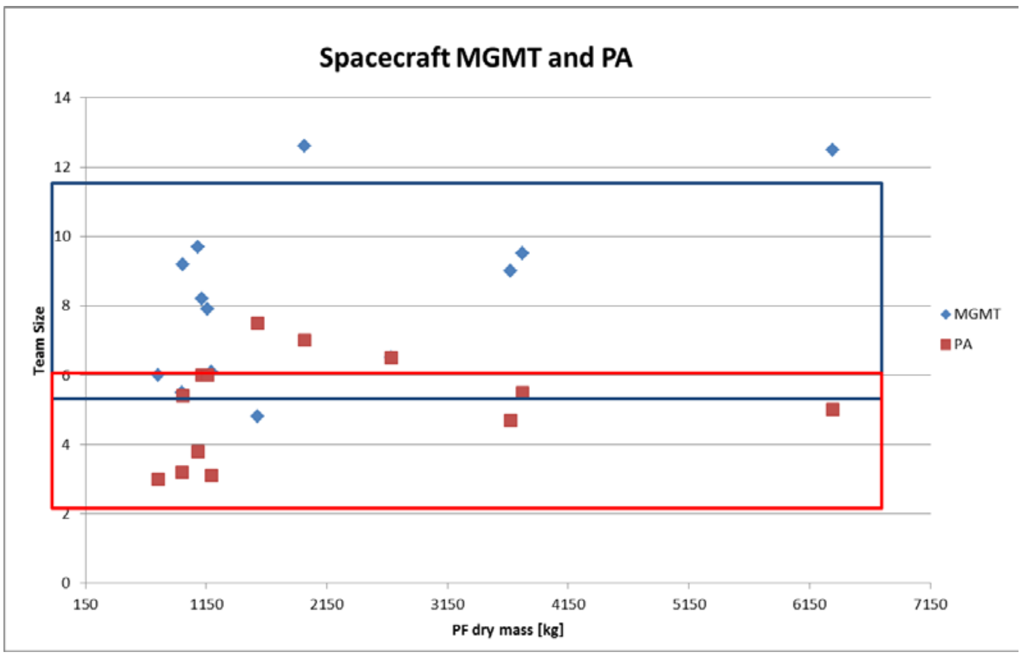

Figure 2. Management and PA team size for various ESA project

Afterwards, 3 families of multivariate equations, refined with an extensive calibration phase, have been defined:

$$Sat\ System\ Team\ Size_{j=}\ f_j(\text{Number of Payloads, Quality level, Industrial set up})$$
$$PF\ System\ Team\ Size_{j=}\ f_j(\text{Quality level, Industrial set up, Platform design Complexity})$$
$$PL\ System\ Team\ Size_{j=}\ f_j(\text{Quality level, Industrial set up, Payload design Complexity})$$

Where j is the j-th subject (Mgmt, PA and System Engineering)

The estimated PO team sizes lead to PO cost through the schedules and the companies' rates.The schedule is one of the most important model inputs and can be defined again at Sat, PF, and PLs level.

For early project phases, when schedule and rates information might not be available, a simplified version of the Schedule Model engine developed in the ESA cost engineering team has been integrated in this PO model., to give a realistic first estimate. It is however recommended , given the importance of this input for the estimation of the PO cost, to use PERT based schedule as soon as available

Schedule slippage

A project schedule extension, related to major design issues (e.g. significant payload redesign) may lead to a reduction, during the extension phase, of some of the team sizes estimated by the model. At the moment, for Subsystem activities, an average team size reduction is taken into account, based on the stretch of the schedule (i.e. it is assumed that a full engineering team is not required in the extended phase , given the fact that most of the design has already been performed). This assumption is only valid if the schedule stretch is identified in full and sufficiently in advance so to allow the demobilization of the non-core personnel in time. ,.System level activities instead are instead hammock type activities thus will the hours growth will be directly prorated to the schedule slippage (for instance, it is assumed that the Project Manager will be allocated full time until the completion of the project). The next model increment do foresee to implement a more rigorous schedule extension impact assessment.

IV. Industrial Set-Up and Subcontractors Role

The inclusion of Subcontractors at System or Subsystem level leads to higher cost than in the case of a single prime contractor. Subcontracting a design activity requires in fact additional prime level procurement and requirement engineering effort (interfaces management). Moreover, the subcontracting of major system activities (e.g. assigning to the subcontractor the responsibility for the Platform), or Subsystem design (e.g. Platform AOCS, Power etc.), due to the strong interdependency between the related design activities, requires an additional PO effort for the coordination with those activities which are not subcontracted (prime own share). Figure II and Figure III show examples of the typical higher manpower effort required for subcontracted activities with regard to technically similar designs.

Based on statistical analysis, specific parameters have been identified to estimate the additional resources required at Satellite and Platform levels to account for the inclusion of Subcontractors.

At Platform level between the subcontracted subsystems, a constant trend, called prime-sub overlap has been identified for each Sub co.

Of course this additional effort represents the best cost option when the subcontracting of an activity is justified by a make-or-buy decision. Since within the European Institutional market the subcontracting of System or Subsystems is often driven by geographical return reasons, the model allows also to account for the degreeof expertise of the subcontracting company through a manual setting of the prime-sub percentage overlap.

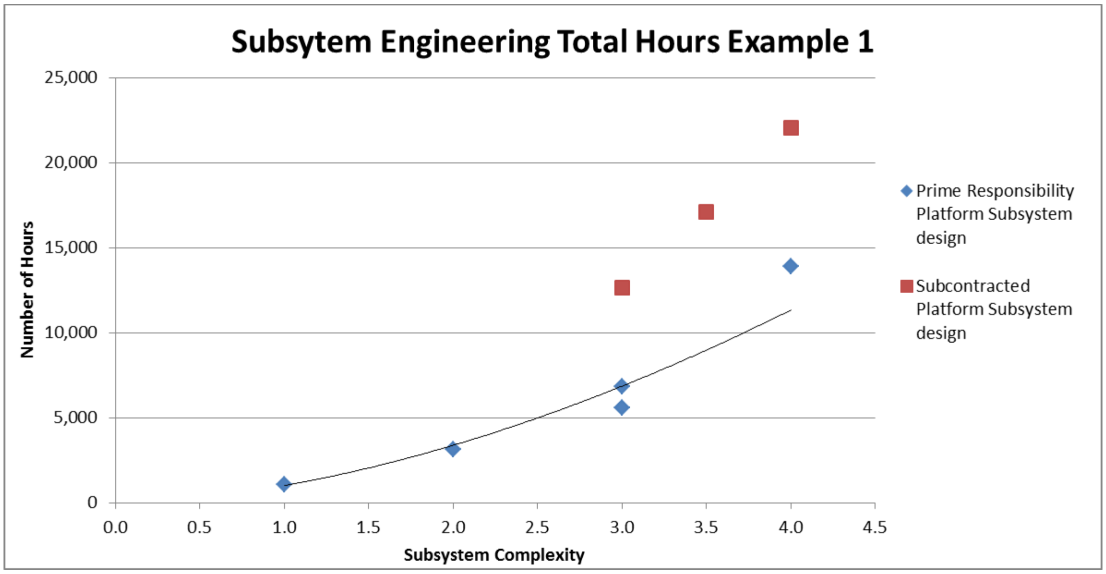

Figure 3. Platform Subsystem level Engineering Design Effort VS Complexity example.

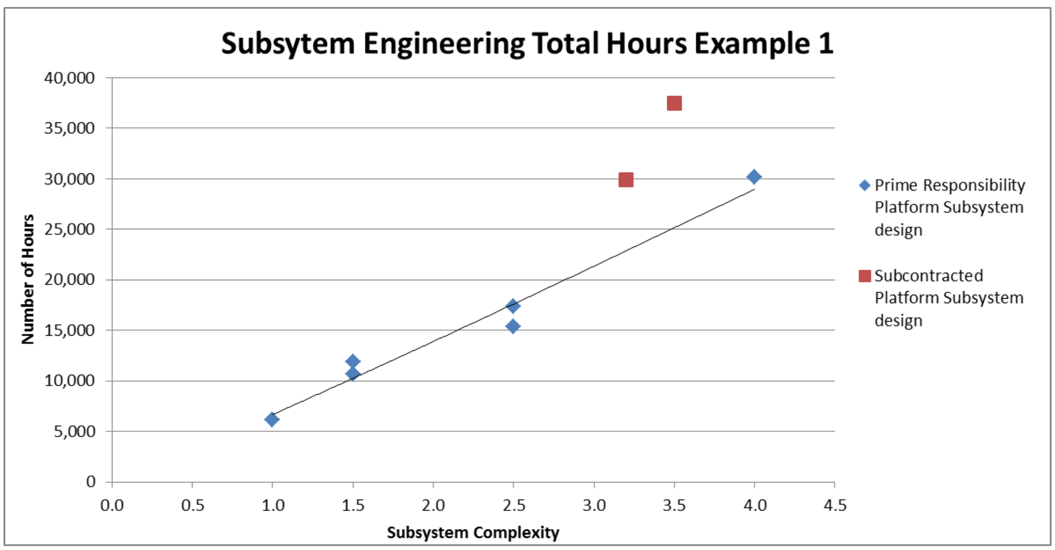

Figure 4. Platform Subsystem level Engineering Design Effort VS Complexity example.

From the figures above, it is possible to appreciate the correction brought on engineering man-hours of a given sub-system due to sub-contracting effect . This correction typically varies between 20 and 40% depending on the following factors:

- Subsystembeing subcontracted;
- Experience of the upper-tierin the specific engineering domain;
- Past experience of the Sub-contractor in the sub-contracted activity;

The following figure shows the tool implementation of this industrial setup options: for each subcontracted subsystem it is possible to define the size and the experience of the subcontractor. This gives a first estimate of the Prime-Sub Overlap factor, that can be slightly adjusted based on calibrations from previous estimates on a case-by-case basis

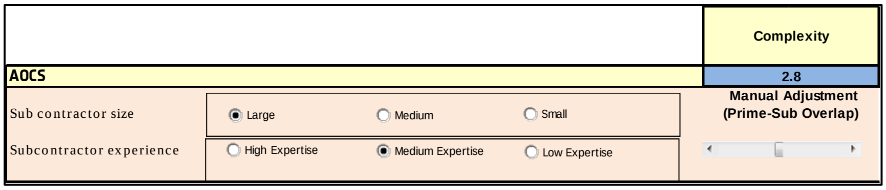

Figure 5. Platform Mechanical Engineering Design Effort VS Complexity

V. Improvements and future Implementation

The model is currently operational for P/F and satellite level PO estimate, but still under development phase for payloads and AIT activities.

In particular for the payloads'case, the amount of data available within the Agency is quite small (if compared to the data available for PF and Sat level), because many instruments, especially in the planetary science domain, are procured directly by the customer therefore their details are only partly available to the Agency. A second family of payloads instead is the one of the so-called CPI (Contractor Provided Instruments), where procurement is managed by ESA. This is a common practice in domains such as Earth Observation, therefore the refinement of the Payload engineering model to support the contractor negotiation process, is of primary interest and will be implemented with the highest priority.

The current level of details of the output of the model is shown in Fig.6. It is possible to appreciate the system level breakdown in Management, PA and System Level Engineering Activities, as well as the subsystem engineering for the Platform. As described before, the cost is derived from team size, average rates and durations. It is also possible to consider delays that affect the total cost as described in section III.

A typical feature of every ESA Cost Engineering models, here well visible, is also the possibility to overwrite every estimate performed by the model (blue background cells), when actual information is available (to be input in green cells)..

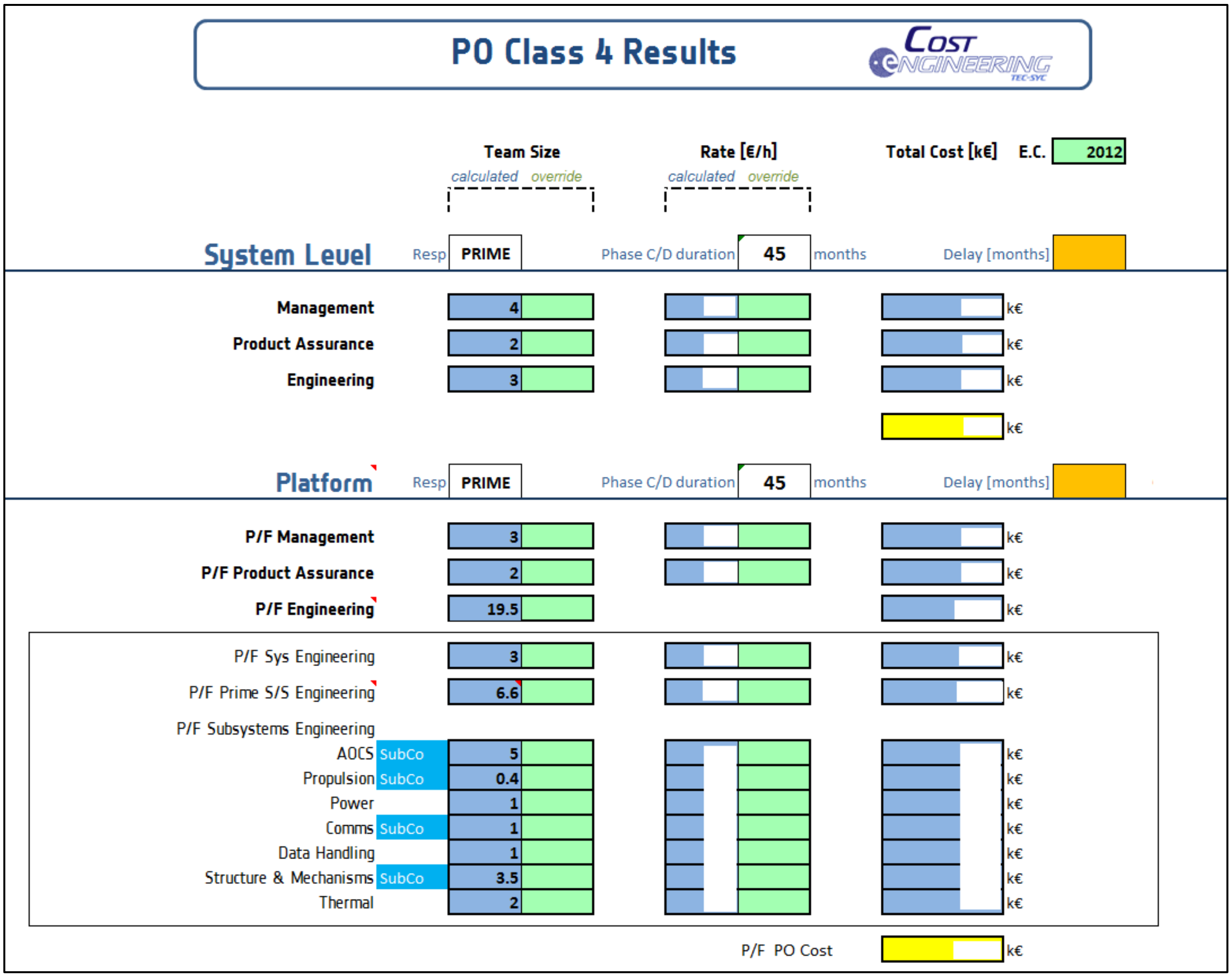

Figure 6. PO cost model Excel tool current output page (partial view with hidden confidential data)

VI. Conclusion

The efforts put in place by the ESA Cost Engineering Section over the past three years have materialized in a fully featured Project Office Cost model that has now reached an operational status.

It has been proven, by several test cases, that the PO cost model provides satisfactory manpower cost estimates. Thanks to the industrial set-up modeling options, the model also proved to be very useful during trade-off analyses and industrial scenario simulations.

The model requires a sufficient system engineering knowledge to correctly apply factors linked to high-level mission characteristics but it is also thought to be used for a very preliminary phase providing a relatively accurate first cost estimate using only a minimum amount of high-level input data.

It is a powerful model for the European Space Agency to evaluate contractors’ proposals and a significant contribution to make even more solid its negotiating position.

Appendix

The following figures show in detail the current tool implementation in MS Excel. Figure 7 in particular refers to the main menu of the tool where it is possible to set some high level mission parameters as well as few qualitative inputs about the foreseen industrial consortium setup.

It is important to underline that the inputs related to the mass are directly taken into account from the schedule estimating model more than from the PO team sizing engine that, as shown in section III, is only indirectly dependent from the size of the spacecraft, and only for some subsystems. (It is straightforward that the design of a TT&C subsystem, for example, is not affected by the mass of the satellite but by link budget parameters).

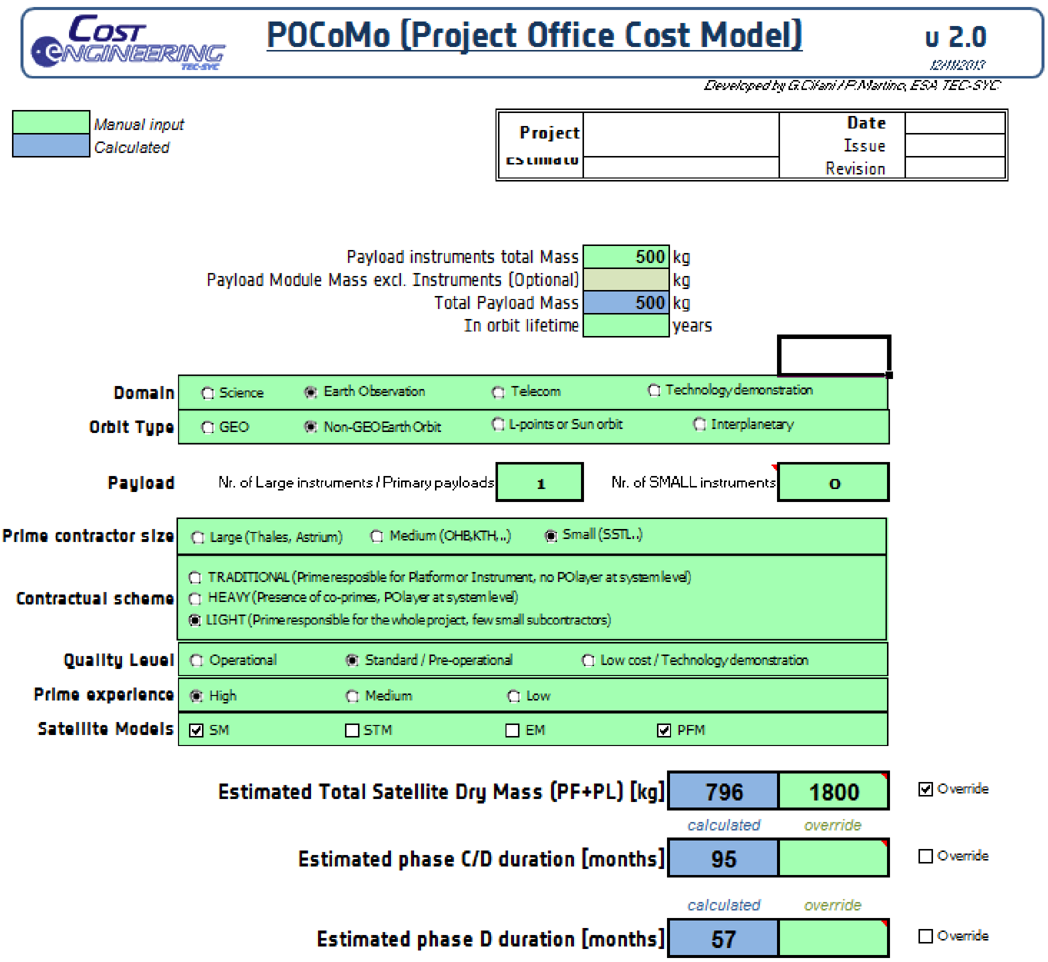

Figure 7. PO cost model Excel tool current system level input page

Another important cost driver, affecting mainly the PA team sizing, is the required quality level of the mission. For instance,a low-cost technology demonstration mission will obviously have lighter PA requirements than a complex long-term operational mission.

In addition, it is important to consider the experience of the prime. At this stage it is intended as experience of the contractor in leading an industrial consortium. (i.e. smaller companies often have more lean and cost effective structures, but they might not be adequate to manage a large and complex consortium. A correction factor set through the "Prime experience" input takes into account this case.)

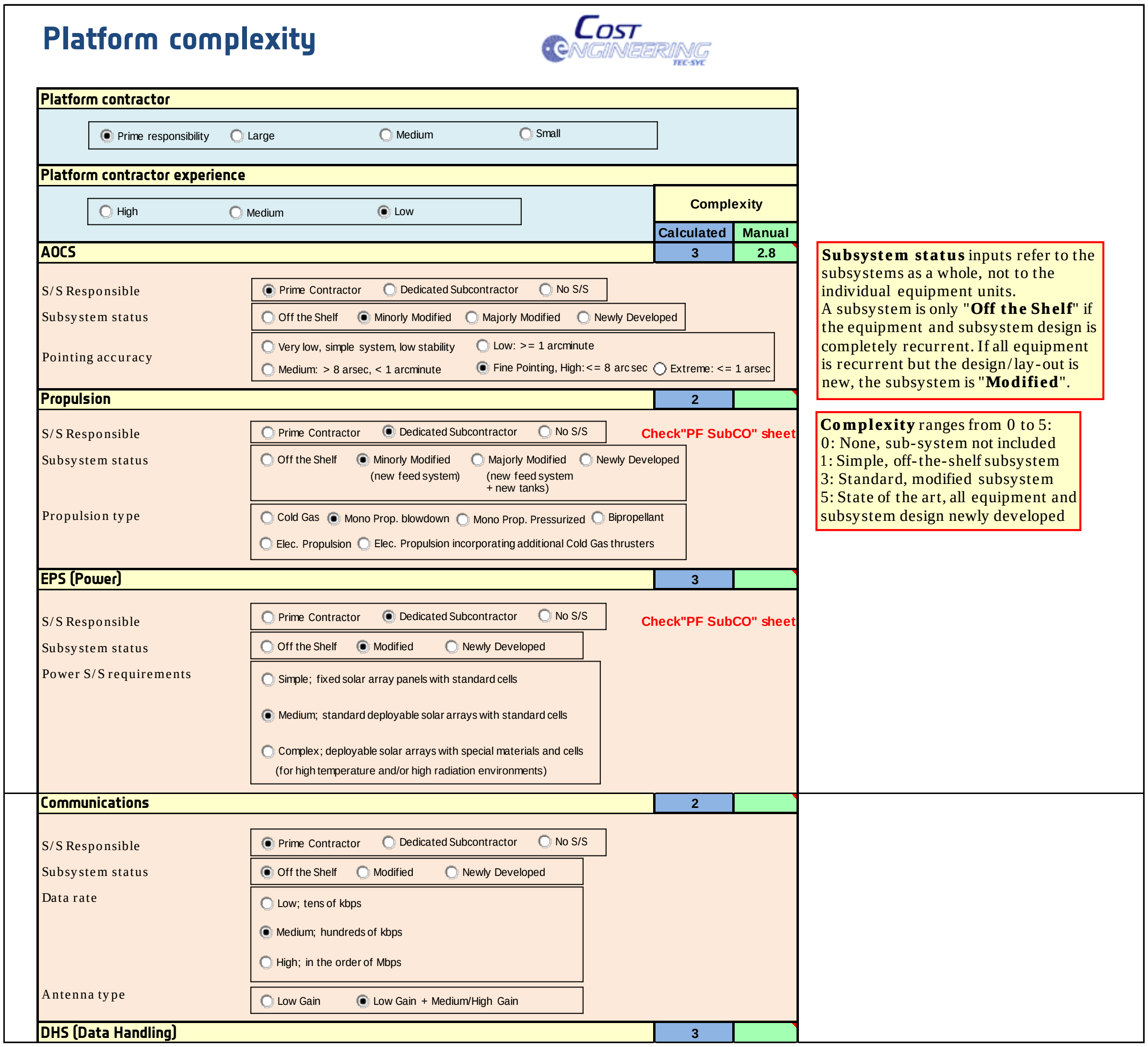

Figure 8. PO cost model Excel tool current PF input page (partial)

Figure 8 shows instead the sheet dedicated to the input of the subsystem complexities. It is shown how for each subsystem it is possible to define if it is either under direct responsibility of the prime contractor or delegated to a subcontractor. The user shall also define some technical and programmatic inputs to define the RACE complexity. It is also possible to define if the platform is under the responsibility of the System level prime contractor or not.

References

[1] ECSS-M-ST-10C Rev 1.

[2] M.O. van Pelt, "The RACE Model: a tool for fast and early cost estimates", *SCAGG 81st Meeting*, 13-14 May 2004, Frascati, Italy.