CloudSat Spacecraft System Acquisition: Teaming for Success in a Changing Environment

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Abstract. NASA's Jet Propulsion Laboratory (JPL) has contracted with Ball Aerospace & Technologies Corporation (BATC) for the design, build, test, and operations of the CloudSat spacecraft. Project personnel have approached the overall contract management task from a teaming perspective since formulation phase. Over time the team has dealt with a number of technical and programmatic changes from adding ballast mass to the spacecraft to an externally driven slip in the launch readiness date. This paper describes specific teaming techniques. Supporting information and data are provided to substantiate the claim that these methods have had a direct bearing on performance. Technical and schedule performance have been and continue to be excellent. Even though cost continues to be a significant challenge, performance has been better than on many other industry contracts. Overall results thus far lend further credence to the axiom that "together everyone achieves more".

Introduction

The CloudSat Project. The CloudSat Project was in competition with a number of other proposals submitted in response to a NASA AO (Announcement of Opportunity). NASA's Earth Explores Program Office at GSFC (Goddard Space Flight Center) selected the CloudSat Project in March 1999. CloudSat is an ESSP (Earth System Science Pathfinder) mission intended to measure the vertical structure of clouds around the world for approximately two years following a launch in the early 2005 timeframe (see Figure 1). By their nature, ESSP missions are cost-capped and are closely monitored by NASA Headquarters and the GSFC Earth Explorers Program Office during project execution. Despite the tight cost constraint and the short development schedule, CloudSat nonetheless has several ambitious aspects that press and perhaps exceed the current state-of-the-art in terms of the total mission scope and planned objectives. Firstly, CloudSat will be the first space mission to operate a 94 GHz CPR (Cloud Profiling Radar) instrument in Earth orbit. This instrument will be used to measure the ice and water contents of clouds. Since this is the only instrument on the CloudSat spacecraft there are no direct means to measure other key cloud parameters needed to perform a more complete and accurate interpretation of the cloud properties. To compensate for this, the CloudSat spacecraft will fly in loose formation with other cloud-observing satellites to facilitate the creation of a complimentary data set of remotely-sensed 'observables'. The loose formation flying partners for this endeavor are the Aqua and CALIPSO (Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations) spacecraft. The CloudSat Project will rely on coordination, co-registry, and near-simultaneous measurements with these other spacecraft and incorporate these complimentary data sources in the generation of CloudSat data products. As far as the in-space formation is concerned, the CloudSat, Aqua, and CALIPSO spacecraft will all fly in loose formation together establishing the lead elements of the PM Constellation of spacecraft (a.k.a. A-Train). This constellation will also include the Parasol and Aura spacecraft as trailing elements.

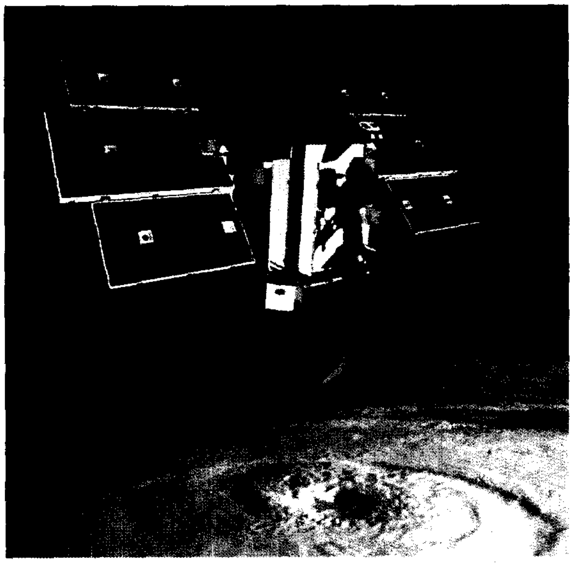


Figure 1. This is an artist rendition of the CloudSat spacecraft in Earth orbit.

Dual Payload Attach Fitting. Another aspect of the CloudSat mission that was enabled by a relatively recent development in the realm of launch services is that CloudSat and CALIPSO will be only the third space launch on a Delta rocket as co-manifested payloads using a Dual Payload Attach Fitting (DPAF). The DPAF is a relatively new development, previously used to launch the EO-1 (Earth Observing-1) & SAC-C (Satelite de Aplicanciones Cientificas C) spacecraft and the Jason-1 & TIMED (Thermosphere, Ionosphere, Mesosphere, Energetics, and Dynamics) spacecraft on single Delta launch vehicles. Unlike the first two DPAF missions, however, this time both spacecraft are to be deployed into the same insertion orbit. Thus, in addition to the formation flying, there are also some relatively new design aspects for the launch and post-injection mission phases.

Partners. From an organizational point of view, the CloudSat Project has participating partners that span a wide breadth. With the Jet Propulsion Laboratory (JPL) as the Project Office, reporting to GSFC's Earth Explorers Program Office, the CloudSat Project is counting on contributions from the United Sates Air Force, the Canadian Space Agency, CIRA (the Cooperative Institute for Research in the Atmosphere) located at the Colorado State University, and BATC (Ball Aerospace & Technologies Corporation). Each of these partners makes its own unique contribution to the CloudSat Project.

Spacecraft Formulation and Implementation Approach. BATC was selected during the proposal stage to provide the spacecraft bus for the CloudSat Project. This was due in part to the considerable design and flight heritage of the flight hardware and software. Although a fixed-price contract was considered, JPL elected to implement a cost-type contract for both formulation and implementation phase. Doing so allowed for and continues to provide better insight into progress and the flexibility to provide technical direction, when necessary. The purpose of this paper is to identify similarities between system engineering and system acquisition (including the change control process) and how the teaming approach between JPL and BATC has allowed for excellent technical and schedule performance and performance on cost that is better than many other industry contracts.

System Acquisition

System Engineering. (Boain, et. al., 2002) regard system engineering as the interdisciplinary activity of defining user needs, defining the required functionality of the system responsive to those needs, and then overseeing/directing the technical design and development effort to assure that the resulting system can be operated to deliver those needs (see Figure 2). Oversight/direction is an activity that involves the ability of performing design synthesis, the ability to make decisions that give consideration to technical, schedule, and cost matters in a timely manner, the ability of assessing that the system design is compliant with requirements at all levels, and lastly the ability to conceptualize how all elements of the system will interact with one another. The oversight/direction step is one of considerable dynamics that sometimes cause iterations in the system design and requirements generation steps.

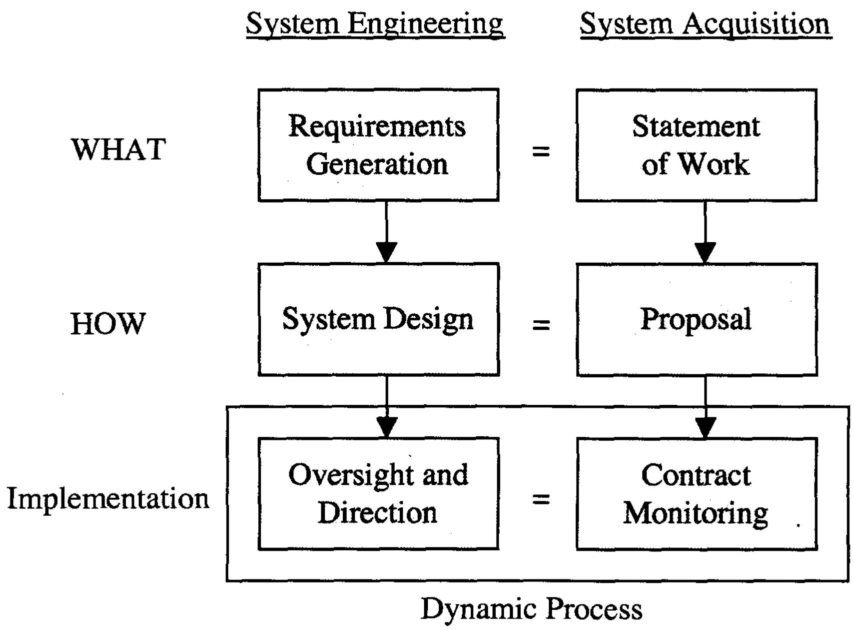


Figure 2. This diagram shows the similarities between the major steps in system engineering and system acquisition. The final steps usually include iterations affecting these and/or the other two proceeding steps.

System Acquisition. The system acquisition process starts with planning and preparation. Defining the job and requirements is one of the most important factors, since it forms the foundation for the remainder of the effort. However, this is typically one of the most difficult tasks. Technical risks, schedule dependencies and constraints, and funding uncertainties must be evaluated along with other factors such as system safety, facilities, and requirements levied by the administrative organization or the sponsor. These must be done before the first step, preparing a statement of work, can be performed. The next step requires the contractor to prepare a proposal that responds to the statement of work. This proposal would include labor, travel, procurements, and/or services as necessary to complete the defined tasks. The third step is contract monitoring. These three steps can be seen in Figure 2. Similar to the system engineering oversight/direction step, the system acquisition contracting monitoring step can be very dynamic. There are several contract technical management techniques that can help to minimize the number of iterations: effective use of time (e.g. schedule adjustments, eliminate or reduce scope, and/or apply additional resources), incorporate simplicity in the design process (e.g. clean interfaces/minimal interdependency and stable architecture, robust and resilient to change), and capitalize on hardware and software heritage.

The Change Process

System Engineering. The system engineering change process is diagramed in Figure 3. The first step requires an individual to initiate a change proposal. A configuration engineer then determines the class of change. Does the change only affect a single project entity or does it affect two or more systems or elements. Depending on the potential scope of the change, reviewers are assigned as appropriate to complete and document impact assessments. A change control board is then convened, so that a cost-benefits trade can be made. Depending on the level of technical risk, and cost and schedule impacts, the proposed change can be accepted or rejected by the convening authority. If approved, the responsible engineer is charged with the follow-up and follow-through process to implement the change. If disapproved, the configuration engineer dispositions the proposed change as such. One can see that this is systematic, multi-step process that typically requires participation by a number of individuals.

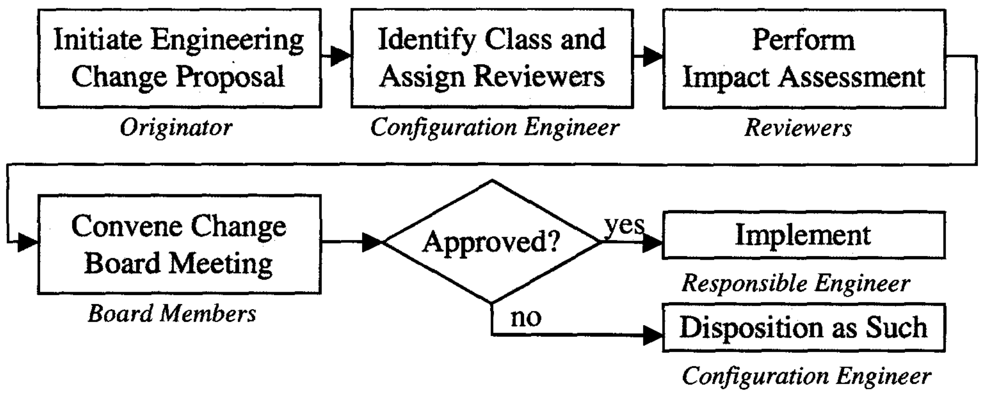
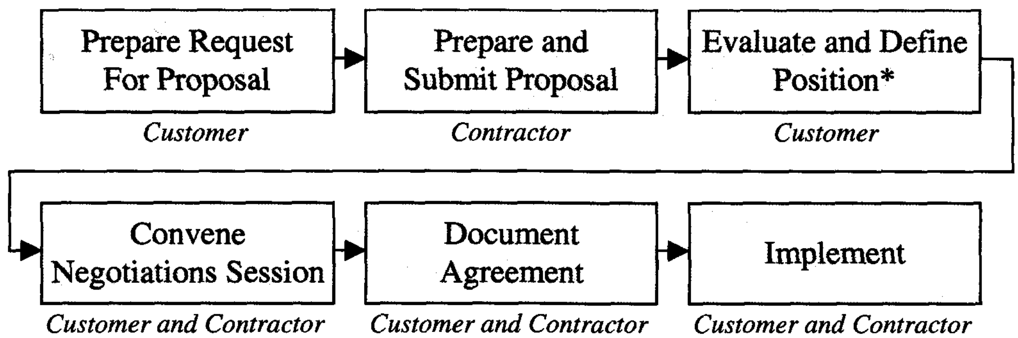


Figure 3. The system engineering change process is systematic, involves a number of steps, and requires active participation by a number of individuals.

System Acquisition. The system acquisition change process is diagramed in Figure 4. The first step requires a request for proposal to be prepared by the customer. This package typically includes a statement of work outlining the specific tasks that must be performed. The contractor then prepares a proposal that responds to this. The customer then evaluates the proposal. If the customer's position differs from the contractor's proposal, a counter-proposal is prepared. A negotiations session is then conducted with the results documented following conclusion of the meeting. The contractor is then responsible for implementing the negotiated changes and submitting revised documentation as appropriate, so that a contract modification can be 'definitized'. One can see that the system acquisition change process is also a systematic, multi-step process that requires participation by and cooperation between customer and contractor. The challenge lies not necessarily with the process, but knowing when and how often it must be exercised, the clarity of the request for proposal package (specifically, the statement of work), the assumptions made in the proposal, the fidelity of the cost estimates, and what negotiated position/mutually agreeable solution will allow for a win-win situation for both the customer and contractor. Now that it is understood 'what' must be performed, the attention can now be turned to 'how' best to complete the system acquisition process, especially in the area of change control.



*Includes fact-finding

Figure 4. The system acquisition change process is also systematic, involves a number of steps, and requires active participation and cooperation by both customer and contractor.

Teaming and Effectively Responding to Change

As stated earlier, this paper will describe the various phases of the project and explain how the teaming philosophy was implemented. Contrast will be made to the more traditional methods of accomplishing the same tasks. The discussion will be divided into three sections that describe the three chronological stages of the JPL/BATC teaming relationship.

Proposal Preparation. BATC was identified as an industry partner early in the process and participated in the development of the proposal submitted to NASA in response to the AO. This instilled in BATC an early and wide sense of ownership of the entire mission and not just their portion of the effort. This was also a cost-effective approach as it eliminated a costly proposal competition phase. Instead of devoting resources in competition with others, BATC was able to make an investment of 'sweat equity' into the project. It also allowed the contractor to see the intricacies of the AO proposal process and the project's requirements as they were generated from the ground up.

Establishing a Contract with BATC. The CloudSat spacecraft system acquisition concept was and continues to be of a one-team effort. A two-camp approach with an 'us versus them' mentality has been avoided. There is an open sharing of information rather than a 'privity of information' approach. The open sharing of financial reserve, for example, allows the reserve to be kept in one location at the project level to be dispersed at the point of need. In contrast, an early distribution of reserve to project partners restricts its deployment to areas of greatest need.

There is a tendency for organizations to retreat to their respective corners and defend their traditional principle interests when problems are encountered. Contractors are required to approach problems in a way that will meet profit objectives and satisfy shareholder interests. The customer's objective is to meet mission objectives and managing taxpayer dollars. Problem solving is often complicated by these differing objectives but can be overcome by developing a basis of mutual understanding and finding a common ground to solve the problem at hand. A win-win resolution may not materialize every time, but it is important to remember that both parties must work to make the mission a success and not keep score of who "wins" more often. The CloudSat project faced such an issue while evaluating the best organization at BATC to perform the work. A decision was reached that took into consideration the needs of the project rather than the parochial concerns of each partner.

Managing the BATC Contract. (Lynch, 2000) states that the traditional working relationship between the customer and the contractor is an arms length relationship. While not adversarial, the parties are each defined and constrained by their own separate, and oftentimes opposed, interests. The contractor is tasked with providing a product or component that will be added to the overall project end product or objective. As such, the contractor's main focus is on technical competence and cost control to maximize profit. The customer is tasked with spending its sponsor's money wisely within the budgetary constraints determined at the beginning of the project. This necessitates following defined government rules concerning expenditures and maintaining a schedule not of the its making while continually focusing on the project's main objective, a successful mission.

Open sharing of project information forms the foundation of our on-going communication methods. This requires trust by both parties that information learned will not be used to take advantage of the situation. Conducting team-building workshops are used to address relationship issues and defuse potential conflicts. Focus is placed on maintaining a civil and respectful working relationship while recognizing the varied personalities of participants. Establishing and maintaining a unified team provided the groundwork for facing difficult project challenges as they arose. For example, dealing with fiscal year funding shortfalls, operating without a definitive plan, and conducting various budget exercises and replans could have had detrimental effects on the health of the project if each party was not willing to work towards the common good.

Lessons Learned. During the course of the last four years, there have been lessons learned in the area of teaming as a result of mostly positive experiences. The most significant of these are listed below.

- Schedule frequent and regular communications between customer and contractor personnel to maintain synchronization. Weekly quiet hours and teleconferences are just two examples, but this can also include monthly management reviews and quarterly reviews.

- Requests must be clear, specific, and have due dates. The requestor needs to be diligent about the follow-up and follow-through process to ensure that the expected information/data is obtained in a timely manner.

- Anyone and everyone in the decision process must be involved as early as possible to expedite matters. What often happens is that assumptions are made on the time it takes to complete certain tasks and the availability of key personnel. To avoid surprises, each individual needs to know what is expected of them and when.

- The customer needs to be diligent in maintaining a cost estimate change log to allow for spot checks and to enable ready explanations.

- Define whether a cost estimate is an engineer's guess, a ROM (Rough Order of Magnitude) estimate that is valid to within some error tolerance, or a formal value that the contractor can stand behind to be absolutely clear about it's fidelity.

- Both customer and contractor personnel must acquire an in-depth understanding of contract administration and technical management processes and procedures to avoid surprises or missing key steps.

- Every effort must be made to avoid changes to the basic structure of the contract (including fee) to minimize disruption unless there are compelling reasons to do so.

- A cost estimate is not firm until it is included in formal correspondence from the contractor. It cannot be overstressed that accurate cost estimates require the contractor to take the time required to obtain inputs from the appropriate cost account managers and to have the estimate reviewed by upper management.

- Each organization should be strongly encouraged to work together as team members. However, it should be understood that when it comes to money negotiations organizations revert back to traditional customer and contractor roles. This is not necessarily a problem as long as each respective organization is aware of, understands, and is respectful of what motivates the other.

- Maintain a lien list to monitor/track potential contract modifications and avoid surprises. This informal lien list allows for both parties to be aware of any potential increase in scope that could impact both cost and schedule.

- Address any interpersonal relationship issues as early as possible. Since successful teaming arrangements require that each individual work well with one another, it is important to ensure that relationship issues are addressed. Unresolved issues can have detrimental effects on the overall performance of the team.

- Schedule a team-building session/workshop with the appropriate individuals. As stated earlier, the customer and contractor, although working towards a common project goal, are also motivated by other means. It is sometimes necessary to bring these individuals together, so that each can appreciate and respect the others needs.

- Surround yourself with capable and experienced personnel who are also team players. Individuals need to understand that team performance can only be maximized if everyone is willing to make a contribution.

Conclusion

Competition is fierce in today's world. The need to perform well from both technical and programmatic perspectives drives many organizations to look for and implement novel approaches. In the past, JPL designed and built most spacecraft in-house with some components, sub-assemblies, or assemblies procured from vendors. Now, more often than not, projects at JPL are accomplished in partnership with academia and industry. In this context, the term partnership represents a major responsibility in the development of the project and/or mission objectives. Although the system acquisition process is well defined and understood, there are teaming approaches that can be employed to improve the overall chances of success. The contractor should be involved as early as possible to instill a sense of ownership. Open sharing of information instills a sense of mutual trust, but it also requires that both customer and contractor resolve not to avoid use that information against each other. The needs of the project take precedence over the parochial concerns of each partner. Finally, both organizations must grow in their relationship by documenting and implementing lessons learned through the development life cycle.

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Biography

Ralph R. Basilio is the CloudSat Spacecraft Manager and (acting) Orbiting Carbon Observatory Spacecraft System Engineer. He has fifteen years of engineering and management experience working on space flight projects including the Space Shuttle, and Galileo, Cassini, Mars Pathfinder, and Deep Space 1 Projects. He is a graduate of the California Institute of Technology's Executive Engineering Management Program, and holds MS and BS Degrees in Aerospace Engineering from the University of Southern California (USC) and the California State Polytechnic University, respectively. He has completed all required coursework at USC for the PhD Degree in Aerospace Engineering and is conducting spacecraft orbital mechanics research leading up to a dissertation in this subject area.

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