National Aeronautics and Space Administration

NASA Case Study

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THE *CALIPSO* MISSION
Project Management in the PI Mode: Who's in Charge?

The *CALIPSO* mission was proposed in 1998 as a pioneering tool for measuring clouds and tiny airborne particles known as aerosols. Carrying the first lidar (light detection and ranging) polarization instrument into orbit, *CALIPSO* (Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations) would enable scientists to build three-dimensional models of Earth's atmosphere and gain a better understanding of the planet's climate system. Among other uses, the models could be applied to pollution control and weather forecasting.

Figure 1- CALIPSO observing Earth's atmosphere. NASA image

By the spring of 2003, however, the mission was facing a host of technical and organizational problems, the project manager had recently retired, and cancellation was not out of the question. (See **Exhibit 1** for the mission development timeline.) *CALIPSO* was a joint mission between NASA and the French space agency *Centre National d'Etudes Spatiales* (CNES) and had been hampered for years by a complex organizational structure and a difficult relationship between Langley Research Center (LaRC) in Hampton, Virginia, which was managing the project, and Goddard Space Flight Center (GSFC), near Washington, D.C. in Greenbelt, Maryland, which had program oversight responsibility for the mission. Communication issues,

management turnover, international regulations, and instrument and spacecraft problems had all presented obstacles. Now, the challenges had converged to push back the project schedule, drive up costs, and threaten the very viability of the mission.

Project Origins

First named *Picasso*, *CALIPSO* was proposed in 1998 by LaRC for NASA's second series of missions in the Earth System Science Pathfinder (ESSP) program. The mission's proposed Light Detection and Ranging (LIDAR) instrument was the maturation of an experiment called LITE (Lidar In-space Technology Experiment) developed in the early 1990s by Langley and carried in the payload bay of *Space Shuttle Discovery* in 1994.

CALIPSO was the only outright selection from the proposals received in the Pathfinder announcement of opportunity (AO-02). *CloudSat*, whose radar measurements would complement *CALIPSO's* lidar observations, was the other eventual winner from the AO, chosen after a follow-up study and downselect.

Once *CloudSat* was chosen, the two missions agreed to formation-fly with the Aqua mission of the Earth Observing System (EOS). They would also be co-manifested on a single *Delta II* launch vehicle.

With *CALIPSO* as the vanguard of the next generation of Earth-science space missions, expectations ran high. "For the first time," said Ghassem Asrar, NASA Associate Administrator for Earth Science, "we will be able to construct three-dimensional structures of the atmosphere to better understand the role of clouds and aerosols in Earth's climate."

LIDAR refers to Light Detection and Ranging and is an optical remote sensing technique similar to RADAR in that it involves bouncing a signal off of a target and using the reflected signal to determine range, motion and densities of the target. The biggest advantage of LIDAR over RADAR is the use of smaller wavelengths gives a LIDAR instrument the ability to capture information about airborne particles which RADAR would not detect. Thus LIDAR instruments are very useful for atmospheric research among other uses for agriculture, archeology and military purposes.

Principal Investigator (PI) Style of Project Management

When the mission originated, NASA was in the early stages of moving toward the principal investigator (PI) mode of project management, an approach advocated by NASA Administrator Dan Goldin. (*CALIPSO* was also conceived in the so-called "faster, better, cheaper," or FBC, era.) The premise was that PIs chosen to lead space-science missions would have complete responsibility for the mission and that minimum project guidance or involvement from NASA would result in more science returns.

There were two schools of thought about this method of management. One view held that the PI mode would lead to increased competition among NASA centers, ultimately benefiting the agency. Specifically, in that view, the PI approach would develop project management capabilities outside Goddard and the Jet Propulsion Laboratory (JPL), where most of the agency's robotic space-flight missions were centered.

The other view argued that flight missions should be done only by Goddard and JPL, simply because it was too costly to replicate project management capabilities elsewhere. This line of thinking had also led NASA to locate the Earth System Science Pathfinder program (ESSP) office at Goddard even though some ESSP projects were managed elsewhere. Goddard's extensive project management expertise was to be leveraged through the program office to all the ESSP projects.

CALIPSO had been proposed by Langley and the PI was located at Langley. However, the project was funded, like all other ESSP missions in the program, through the program office at Goddard. Based on the emerging PI mode of management, however, the program office was expected to apply only "light touch" oversight to the *CALIPSO* mission, allowing the PI team to manage it. This was in accordance with the AO:

> *The Principal Investigator and mission team will have full responsibility for all aspects of the mission, including instrument and spacecraft definition, development, integration, and test; launch services (if acquired by the mission team) or mission launch interfaces (if launch service is NASA-provided); ground system; science operations; mission operations; and data processing and distribution…. It is the intent of NASA to give the PI and the mission team the ability to use their own processes, procedures, and methods to the fullest extent possible.*

Project Organization Structure

The GSFC/LaRC Divide

Notwithstanding the announcement of opportunity, the centers running *CALIPSO* took very different positions on the responsibility for project management. The Langley director was interested in his center gaining prowess in full flight-mission project management. Further, as funding for aeronautics was decreasing, LaRC envisioned Earth science as a growing piece in its budget pie. The director wanted to bypass the program office at GSFC and report directly to NASA Headquarters (HQ); he made such a request many times. The director's logic was that LaRC deserved a chance to prove itself in flight project management just as it had over the years for flight instrument management.

The GSFC director, on the other hand, took the position that Goddard had a proven, and current, track record of flight mission management. By contrast, Langley had not managed a full flight mission since the *Viking* journeys to Mars in the 1970s.

NASA HQ defined and confirmed the roles and responsibilities as follows. Langley, with its principal investigator leading the project, would serve as the mission office and be responsible for the development of the primary science instrument. Goddard would provide high-level technical and programmatic oversight—again, with a light touch—through the ESSP program office and in its role as the lead center.

Mission Partners

The *CALIPSO* project structure was not confined to NASA and the United States. The mission was a partnership with *Centre National d'Études Spatiales* (CNES), the French space agency, including a co-

principal investigator role from the French research organization *Institut Pierre Simon Laplace*, named for the great French mathematician and astronomer who in the early 1800s theorized about black holes.

Under the NASA–CNES memorandum of understanding (MOU), CNES would provide a number of components and services, including the ground stations, satellite operations, and tracking, as well as integration of the payload onto the spacecraft bus and for satellite-level testing. CNES was also responsible for one of the three science instruments, the imaging infrared radiometer, to be built by the French firm Sodern, and for providing the *Proteus* spacecraft bus, to be built by the French company Alcatel, located in Cannes, France (See Figure 2 for a diagram of the organizational structure.)

Also on the team was the U.S. firm Ball Aerospace & Technologies Corp. (BATC). Under contract to Langley, BATC was responsible for designing and building the CALIOP lidar (Cloud-Aerosol Lidar with Orthogonal Polarization), the main instrument on the satellite (see Figure 3). Ball was contracted also to deliver a wide-field camera, the third instrument in the payload. Its facility in Boulder, Colorado would serve as the location for integration of the three instruments onto a payload module. The company was responsible for delivering all ground equipment to test, calibrate, and install the payload module onto the spacecraft bus. In addition, BATC would support Langley in the interface definition between the payload module and the bus and in the installation of the payload module onto the spacecraft at the Alcatel facilities. Given the number and disparate location of the mission's major players, the potential for unwieldy management was a risk.

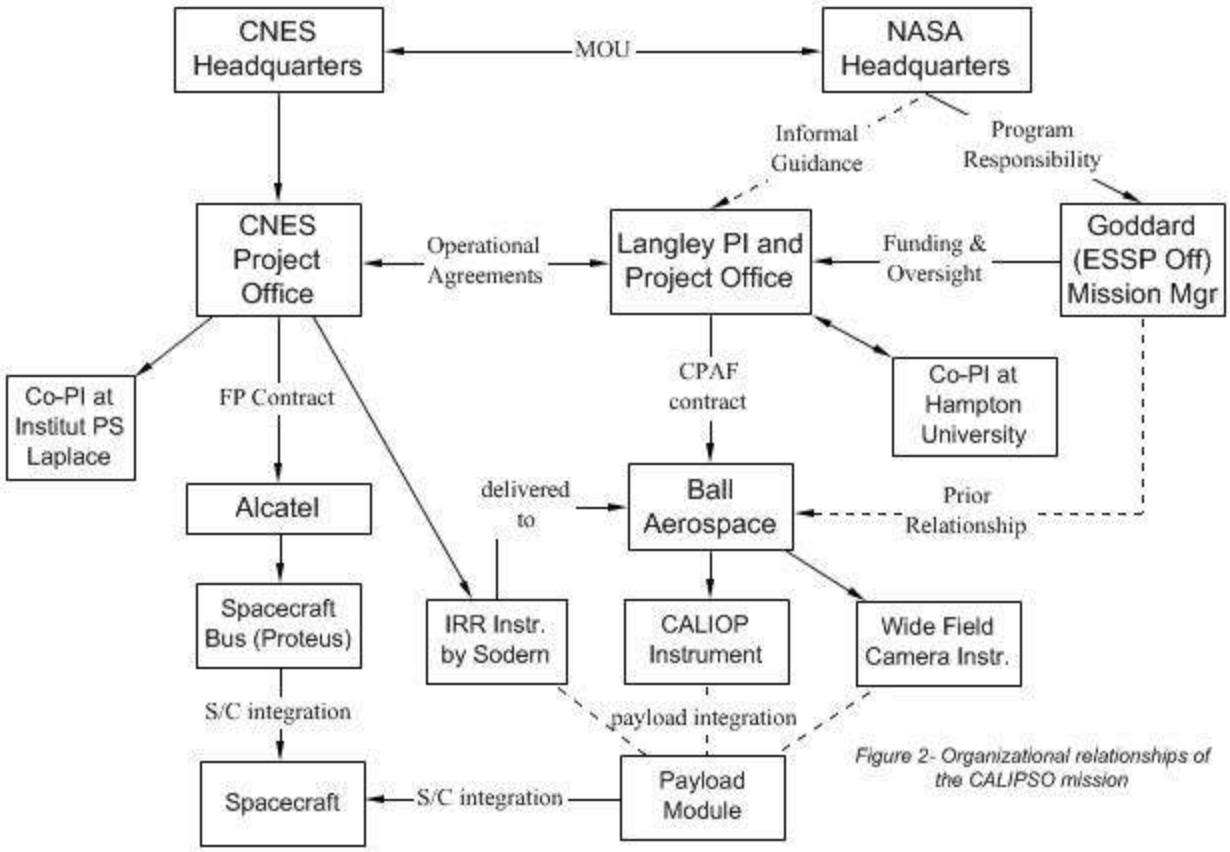

Figure 2- Organizational relationships of the CALIPSO mission

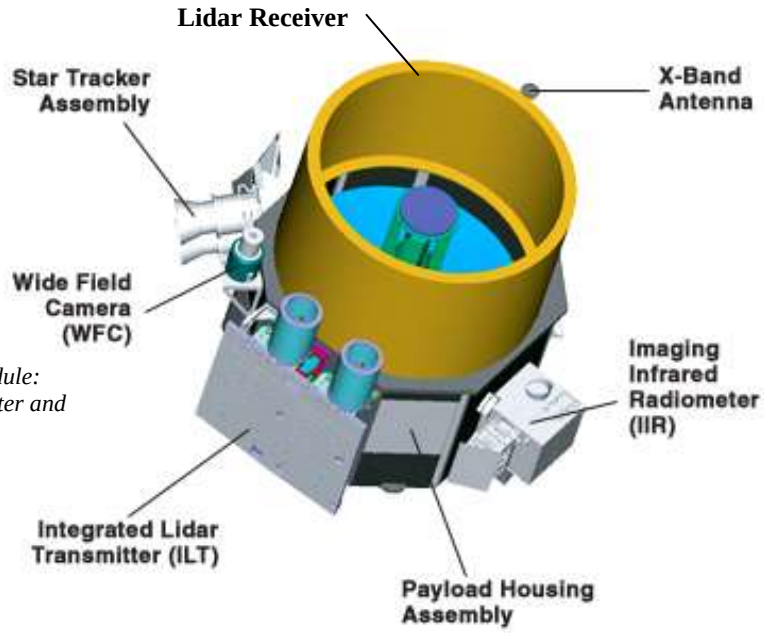

Figure 3 - The CALIPSO payload module: Lidar telescope with infrared radiometer and wide-field camera. NASA image

Mission Management

During the early phases of *CALIPSO*, implementation went along relatively normal lines, and Goddard followed the light-touch approach to oversight. The mission manager (MM) was located at Goddard and reported to the program office there. He interacted with the project office at Langley, and served as the conduit for technical support as requested by Langley and project oversight for the program office at Goddard.

This approach was consistent with other missions in which LaRC had been responsible for delivering instruments to GSFC-managed projects. And prior to *CALIPSO*, LaRC had partnered successfully with program-office mission managers at other locations, including NASA HQ and Johnson Space Center, as well as at GSFC. For example, the CERES (Clouds and the Earth's Radiant Energy System) instrument had been developed at LaRC and flown on the Goddard-led *Terra* and *Aqua* missions. LaRC had also engaged successfully with Russian, French, and Italian firms in cooperative endeavors for instrument deliveries.

But questions about the management organization persisted among the Langley team:

1. If the project was centered at Langley and reported to the program office at Goddard, why was the project manager at Langley reporting to the MM instead of directly to the program manager at Goddard?

2. If the MM was to be part of the project team—as the program manager had said—why wasn't he located at Langley?

3. For that matter, why have an MM at all if his only function was to act as a link between the program manager and the project manager?

4. In the PI mode, wasn't the PI supposed to run the mission? What did the original AO mean when one center has program responsibility and another has project responsibility?

Members of the Goddard management team had concerns, too:

1. How could they be expected to be responsible for mission management if they did not have the authority to oversee the overall schedule (and had little confidence in LaRC's schedule)?

2. How could they provide oversight when they didn't know what all the partners and contractors were doing?

3. What was the overall responsibility split between the program office, at GSFC, and the project office, at LaRC? What exactly was the role of the lead center?

4. Who was HQ holding accountable for mission success? Why wouldn't HQ clarify roles and responsibilities?

Other issues were cropping up--the Langley team, for example, was having a hard time getting the contract with BATC in place. Then, in the spring of 1999, the associate administrator for Earth science issued a directive that lead centers should take responsibility for running Mission Readiness Reviews (MRRs) and certifying flight readiness. Now it appeared that Langley and Goddard were equally responsible for the *CALIPSO* mission. In that light, the GSFC director felt it was even more necessary for Goddard personnel to be directly involved in *CALIPSO*—essentially, to have more oversight—if they were going to be held accountable for the outcome.

Later the *CALIPSO* project manager appointed near the end of project development, reflected on the different backgrounds of the two centers and their approaches to the mission:

> *"What's good about Langley is their technical work. But this sometimes resulted in turning an engineering concern into a performance issue that had to be resolved before continuing. This made it difficult to stay on schedule. The consequences—mainly on the budget—of not holding a schedule were not always factored into 'work on the floor' decisions. One of the things that stood apart in how Langley did things is that management did a lot of hands-off delegating: Give somebody a job and expect it to be done. That was far from the way at Goddard. So the Langley project was always being second-guessed. The light touch went out the window. It created a tense environment."*

The program manager for *CALIPSO* in a later stage of development, considered the principal investigator management approach:

> *"The PI mode has always been problematic. PIs tend to be scientifically competent and understand the community they're involved in. They need to rely on each organization's strengths, but they can't help but be thorough end to end. A good project management team will temper the PI by providing programmatic balance to technical/performance decisions."*

To gain confidence in the technical approaches LaRC was taking on the project after the new directive from HQ, an increasingly large "shadow team" at GSFC began to mirror Langley's work. Predictably, the feeling at Langley was, "They don't trust us." Within LaRC, some team members felt they didn't have the complete support of upper management and wondered whether certain senior managers really wanted to get into mission management at all.

At the same time, there was a sense among some Goddard managers that Langley was keeping them in the dark. Despite frustration with the way the program was being managed, the LaRC and GSFC teams maintained good, productive working relationships. According to members of both teams, personnel at both centers placed much of the blame for management confusion on NASA Headquarters.

At the technical level, problems were flaring up with both the LIDAR, at BATC, and the spacecraft. It was known from the beginning that the CALIOP instrument would be a challenge. At Goddard, issues with the recent Vegetation Canopy Lidar (VCL) and laser development on the *ICESat* mission were still fresh, resulting in the center being much more critical of the CALIOP instrument development on *CALIPSO*. For its part, Langley felt that its experience on the LITE project and its joint effort with BATC and Fibertek developing and testing the risk reduction laser more than adequately addressed Goddard's concerns.

BATC, meanwhile, was in the awkward position of having communication paths and relationships (and loyalties) with both LaRC and GSFC, a situation that often made feedback and prioritization difficult and inconsistent.

International problems

There were similar relationship issues with the foreign partners. In addition, the U.S. International Trafficking in Arms Regulation (ITAR) was complicating the interfaces with CNES and Alcatel. Under ITAR restrictions, Langley was finding it hard to share information with the CNES/Alcatel team, and the French representatives were sometimes required to leave project meetings when ITAR-sensitive material was discussed.

Language barriers also presented issues that afflicted the U.S.–French relationship. Later, the *CALIPSO* project manager, thought back on the challenges posed by the international partnership:

> *"With our relationship with the French, we had to sit down with them when there were problems—e-mail didn't work, telecons didn't work. What worked best was to go over there and sit down and discuss things. They didn't like being told, "Here's the problem and solution—take care of it." There were enough idiosyncrasies in the language barrier to make it difficult. For example, 'demande' in French means 'request,' not 'demand.'"*

The French were alternately frustrated and insulted. As a result, CNES at times refused to provide reciprocal information when requested. The GFSC Project Manager reflected on ITAR:

> *"Working the interfaces between the payload and the spacecraft bus was an enormous problem. This would not have been the case if it had been a wholly domestic project, with a prime contractor interfacing the instruments…. ITAR is a huge challenge to NASA international partnerships."*

To both the domestic and international partners, there was one overarching issue. The mixed management signals emanating from the two NASA centers to BATC and CNES were confusing: Who was really in charge of the project?

At the same time, problems with the Jason spacecraft, the first Proteus Bus, had an impact on the CALIPSO spacecraft that caused the Preliminary Design Review (PDR) to be delayed until July 2000, which, in domino fashion, pushed back the combined mission PDR/MDR (Mission Definition Review) from April 2000 to September 2000.

More than a year and a half after *CALIPSO* was chosen as the only direct selection in the second ESSP mission series, heralding a new era of Earth science discoveries from space, project leaders found themselves on the defensive. And critical mission reviews were approaching.

Fractious Reviews

The MDR panel was made up of experienced senior project managers and engineers, mostly from Goddard (or retired Goddard personnel), with one independent consultant. The reviews, which were held over the course of five days in September 2000, did not go well. The panel focused on what it saw as a lack of demonstrated management at Langley, especially in laying the groundwork with CNES and interfacing with the French agency. LaRC was heavily criticized on cost and schedule management issues. And with BATC presenting the bulk of the project material, the review panel was left with the negative impression that Langley was not in control of its contractor.

Overall, the GSFC reviewers embraced the notion that LaRC suffered from inexperience with end-to-end flight systems. While the LaRC team felt abused by the review process led by Goddard personnel, GSFC, feeling responsible for the mission, was worried not only about the outcome of the project, but also about Goddard's reputation.

Two months after the contentious preliminary reviews came the Mission Confirmation Review (MCR) at HQ, to determine if the project was ready to proceed from the formulation stage to full implementation. Based on the PDR/MDR, the outlook was not bright. By now—November 2000—serious reservations had surfaced concerning the project plan and implementation.

Aware of the concerns raised about project viability, HQ delayed the confirmation approval for several months, until the spring of 2001. Even after a successful confirmation review, cost and schedule issues continued to dog the project for the next two to three years, with the threat of project termination.

Management Upheaval

CALIPSO struggled forward, driven by a determined and dedicated project team. But by mid-2002, there was an unavoidable sense that a replan was needed. Periodic attempts to forge a new, more effective management relationship for the good of the mission resulted in still more changes in program/project personnel at both LaRC and GSFC. The program and project launch readiness schedules differed by about a year. Technical glitches and failures in the instrumentation had occurred. There was friction between all parties, if not among team members themselves.

Finally, in autumn 2002, a new mission manager was assigned at Goddard and the project underwent changes in the management ranks at both centers. Then, in the spring of 2003, came still more change: The project manager at LaRC retired, leaving a leadership void.

Rick Obenschain, The Goddard Director of Flight Programs and Projects at the time, would later size up the problematic development of the mission:

> *"This was a situation that was so far off the tracks... The job at hand was to produce a mission. It would not be a success—a mission success or a science success—until it was a management success."*

Exhibit 1

CALIPSO Mission Development Timeline

Event	Date
Mission selection (originally called *Picasso*)	December 22, 1998
Picasso kick-off meeting at GSFC	January 25, 1999
Directive from NASA Associate Administrator for Earth Science: All lead centers to use Program Management Councils to run mission readiness reviews for flight missions, certify flight readiness	March 1999
Picasso project kick-off meeting at LaRC	April 19–23, 1999
CloudSat co-manifested	May 1999
LaRC/BATC contract signed	August 10, 1999
Systems Requirements Review (SRR)	January 2000
Proteus spacecraft Preliminary Design Review (PDR) at Alcatel in France	July 2000
PDR/MDR (Mission Definition Review)	September 18–22, 2000
Mission Confirmation Review (MCR) (confirmation delayed)	November 15, 2000
Delta MDR	March 2001
Delta Confirmation Review (program/project approval)	April 2001
Critical Design Review (CDR) (also called Mission CDR)	March 18–22, 2002
Delta MCDR	September 2002
New program manager assigned at GSFC	November 2002
Project manager retires from project and LaRC	March 2003