A Risk Mitigation Approach to ALMA Antenna Procurement

R. L. Brown
(draft 24 August 2001)

1. Overview

In the tripartite ALMA Project, the partnership of Japan, Europe and North America, the procurement of 64 antennas of 12 meters diameter that meet the ALMA specifications will require an estimated expenditure of nearly one-quarter of a billion U.S. dollars. Because of the cost, the antenna procurement is the most visible task in the ALMA Project. The addition of Japan as a third partner in ALMA certainly brings greater resources and greater scientific capability to ALMA. But for those shared tasks for which the scope does not change with the addition of Japan, tasks such as the procurement of 64 antennas, the need to share and coordinate the procurement among three partners rather than two complicates the procurement and increases the risk. In order to mitigate that risk we suggest a procurement strategy that seeks to confine the risk to those issues that the Project can manage internally, and to eliminate or strongly limit the risk that arises as a result of the actions, or inactions, of external parties or circumstances.

2. Issues and Processes that Inform the Proposed Risk Mitigation Procurement Strategy

The proposed procurement strategy is derived in recognition of the following considerations and events:

Global Project Considerations

- ALMA is a cost contained project;
- ALMA is a schedule constrained project;

These considerations come from the three ALMA Partners. We will build ALMA for the construction cost agreed upon initiation of the construction project and on the schedule agreed at that time. We will not use operating funds or ancillary funds to construct ALMA, nor will we extend the construction project in time beyond that agreed. The management *variable* in the ALMA Project is scope.

Current Project Realities

- The EIE prototype antenna delivery is delayed (to October 2002 or later);
- There exists no contract for a Japanese prototype antenna;
- A “Japan factor” can expect to be paid on research equipment procured in Japan.
- The process of securing funds for ALMA by NAOJ is aided by strong industrial support in Japan; antenna design and fabrication is the most visible industrial contribution to the Project. Hence strong Japanese industrial involvement in the antenna procurement is important to NAOJ.

Advice from the ALMA Management Advisory Committee

The AMAC urged the Project to centralize responsibility for a build-to-performance contract with a single contractor. This advice is given to minimize risk. Specifically, the AMAC advised:

> *The* [antenna procurement] *strategy should not lose sight of the ultimate goal of producing the set of ALMA antennas that meet specifications and are mass-producible within budget. …Multiple sourcing of antenna components and systems, while providing program redundancy, will burden quality assurance and lead to likely dispersion of delivered specifications that must be included in the ALMA system-engineering process.*

Schedule for the 3-way ALMA Project

The delivery of the production run of 64 antennas to Chile is the pacing task of the ALMA Project. For the 3-way Project, the Expanded ALMA Executive Committee (E-AEC) has adopted in its planning the following schedule for antenna delivery to Chile (this schedule has not been approved by the E-ACC):

2005 October	First production antenna accepted in Chile (at the OSF)
2006 February	Outfitting and engineering evaluation of #1 complete
2006 December	10 antennas in Chile (9 antennas delivered in 2006)
2007 December	25 antennas in Chile (15 delivered in 2007)
2008 December	40 antennas in Chile (15 delivered in 2008)
2009 December	55 antennas in Chile (15 delivered in 2009)
2010 December	64 antennas in Chile (9 delivered in 2010)

Process to go from Prototype Antenna to Production Antenna Contract

Upon delivery of each of the prototype antennas at the ALMA test site near Socorro, New Mexico, the antennas will be outfitted with ALMA-provided metrology equipment and control instrumentation. The antennas will be tested for mechanical performance. This will take approximately 3 months. When it is complete, the holography equipment will be installed and the reflector surface will be measured and set. Following this, the radiometer will be installed and tests of gain, pointing, tracking, and stability will be made; the antenna in this mode is being used as a single dish. Quite good measurements of all these “single dish” parameters can be made (e.g. pointing on the limb of Jupiter, optical pointing on stars) over all environmental conditions (sun, wind, temperature changes). These measurements will require approximately six months. Once they are finished the antenna is ready to be used with another prototype antenna in a program of interferometric tests. Six months of interferometric tests are planned specifically for the purpose of competitively evaluating the performance of the initial two prototype antennas; a decision will be made as to the antenna with the best technical performance.

The next steps involve a negotiation of the contract for the production run of 64 antennas including negotiations for whatever technical modifications we wish to have incorporated in the final design. Approvals by the finance committees and legal staff of the three ALMA partners will follow culminating in a signed contract.

The process and timescale is summarized step-by-step below:

Table 1: Antenna Procurement Schedule and Process

Task	**Total Elapsed Time to Task Completion (i.e. time elapsed since antenna acceptance)**
Milestone: Prototype Antenna Acceptance	0 Months
Milestone: Delivery by the Prototype Contractor of "*a binding firm fixed price for the production antennas in response to a formal request for quote (RFQ) for production antennas to be issued by AUI"*[ESO, NAOJ][1]	1 Month
1. Outfitting, Mechanical, Servo Tests	3 Months
2. Holography, Radiometric Tests (e.g. gain, pointing, etc.)	9 Months
3. Antenna Ready for Interferometric Tests	9 Months
4. Interferometric Tests Specifically for Competitive Antenna Evaluations	15 Months
Milestone: Selection of best performing prototype antenna	15 Months
5. Negotiate Contract for Production quantity antennas→best and final price	18 Months
6. Contract Evaluation and Partner Approvals	24 Months
Milestone: Sign Contract for Production Antennas	24 Months
Milestone: Delivery of First Production Antenna to OSF in Chile	36 Months
7. First Production Antenna Outfitting; Validation Tests	40 Months
Milestone: Acceptance of First Antenna in Chile	40 Months
Milestone: First Antenna Moved to Array Site	40 Months

[1] Atacama Large Millimeter Array: U.S. [ESO] Prototype Antenna Purchase Order, April 2000.

3. Risk in the Antenna Procurement

The schedule shown for the antenna procurement process has very little slack. The slack that may be present would arise as a result of favorable weather, for example if the interferometeric tests are done in the winter months the time required could be compressed from six months to perhaps as little as four months. Working in the opposite direction is the time allocated to contract negotiation and approval. The three months of contract negotiation, and six months for the approval process certainly assumes that there are no major hurdles to overcome. We conclude from this analysis that 40 months are required from the time the prototype antennas are delivered to the time that the first production antenna arrives at the OSF in Chile.

Risk #1: Schedule

The first of the prototype antennas scheduled for delivery to the VLA ALMA test site is the VertexRSI antenna. The company maintains that it will be erected and delivered to AUI/NRAO on 23 April 2002. Using this is a baseline date, and adding 40 months to it, the schedule would have the first production antenna arriving in Chile in August 2005. This is two months prior to the Project goal of having the first antenna in Chile on October 2005. The schedule has 2 months slack.

However, the 40 month schedule from delivery of the prototype antenna to the VLA ALMA test site, and the delivery of the first production antenna to Chile, assumes that both the European prototype antenna and the VertexRSI prototype arrive at approximately the same time so that interferometric observations can begin 9 months later (task 3 of Table 1). If we now recognize that the European antenna will be delayed to October 2002, the procurement schedule slips by six months. The first production antenna could not be in Chile before February 2006.

The schedule for the NAOJ prototype antenna adds to the schedule risk. Currently, NAOJ is estimating delivery of their prototype antenna to the VLA ALMA test site in April 2003. If this antenna is to be evaluated in the same manner as the other two antennas then the impact on the schedule is twelve months. Taken at face value, this risk would have the first production antenna in Chile in August 2006, ten months later than desired. Some part of this delay could be made up: the antenna testing team at the ALMA test site will have the experience of testing the first two antennas to speed their work on the third. Perhaps this could save a month or two if everything went well.

The other area of schedule risk is associated with the time required to negotiate a contract with the antenna contractor or contractors. In the bi-lateral North America-Europe ALMA Project, it had been assumed that the two Partners would negotiate with a single vendor asking that the contract be written with approximately equal offsets of work going to North America and Europe respectively. The antenna procurement schedule in Table 1 is structured with this model in mind. However, if now there are three partners wishing to share the work then the contracting entity and structure is much more complicated. This is particularly true if the Partners wish to have the work shared by the vendors of their respective prototype antennas rather shared by a single vendor offsetting work to subcontractors in the countries/regions of the three partners. In June the E-AEC discussed with the AMAC variants of these two models, the "vertical" and "horizontal" model respectively. The AMAC saw difficulties with both models and suggested we look for alternative approaches. Jaap Baars has been investigating this question and has suggested a "diversified model" the hallmark of which is that we (ALMA) require the vendors of the three prototype antennas to establish a "joint venture", using the legal structure they find most appropriate, and that joint venture is the entity that provides the ALMA antennas[2]. The viability of this approach, and the timescale for its implementation, is uncertain. And for this reason it is an area of schedule risk.

Risk #2: Cost

The antenna costing that is being carried by the project is based on the production-quantity estimates provided to us by VertexRSI and EIE, respectively, as part of the contracting for the ALMA prototype antennas. These estimates will be refined for us by the vendors at the time of CDD. The management tool we have used to control the antenna costs is competition: VertexRSI and EIE are keenly aware that they are competing for the same antenna production contract.

In a strictly "vertical" procurement model where there are 3 antenna vendors independently building to the same design, the cost risk increases because the costs of NRE, tooling and management are paid three times. The profit on the contract to each vendor is also amortized over a smaller quantity leading to larger per-unit cost.

In a strictly "horizontal" procurement model where there is a single vendor (or "integration contractor") who must forge subcontracts of equal value in all three regions or countries the cost will increase as a result of the vendor not being able to use the lowest cost bidder in many cases. In particular, the project would bear whatever "Japan factor" would be applicable to those components provided by Japanese subcontractors.

In the "diversified procurement" model[2] where the three vendors are required to form a joint venture we eliminate all cost competition because the three companies that have demonstrated the capability to build an antenna to the ALMA specifications are told in advance that they will get one-third of the work each. In this case, there is little incentive to keep the cost down, the only incentive being the threat that ALMA can contract with any one of them based on the fixed price they provided to us at the time they delivered their prototype antenna (see Table 1, second milestone). Finally, again in this model it is ALMA that will be accountable for the "Japan factor" because the Japanese vendor will be a direct party to the cost negotiation with ALMA through the joint venture.

Risk #3: Technical Performance

In their report of their June 2001 meeting, the AMAC notes:

---

[2] J. Baars *The Diversified ALMA Procurement Model-2* Draft 20 July 2001

> *The* [Antenna Procurement] *strategy should not lose sight of the ultimate goal of producing the set of ALMA antennas that meet specifications and are mass-producible within budget.*

What this important remark says is that the technical risk is the risk that we cannot provide to the Project an antenna that meets the ALMA specifications. The risk is not that we cannot choose the "best" antenna, but rather that we cannot find a way to design and build an antenna that meets our specifications.

The strategy to this point has been to contract for three prototype antennas with three different vendors all of whom are working to the same set of specifications and interfaces. This minimizes the risk of our being able to find one of the three, at least, that will satisfy the ALMA specifications. For this reason, the technical risk is well controlled through the prototyping phase.

For the production antenna procurement the different procurement models bring different risks. In any model in which critical technology has to be shared by more than one manufacturer the risk increases. Just because one manufacturer can fabricate a particular technology to a certain set of prints does not at all mean another manufacturer can do so—particularly if the second manufacturer was not involved in the design of the technology. This is particularly true of CFRP technology on which all of the ALMA antenna designs are so dependent. For all such critical technologies a single contractor working with his own staff (or his own contract staff) in his own facility is the lowest risk. Sharing that technology as in the vertical model is high risk. The risk potential is still there in the horizontal model, depending on how subcontracting tasks are handled. The diversified model handles this particular risk well (many options). It also has the advantage of handling the "production rate" risk well: with three involved contractors if one contractor becomes delayed the other two could, in principle, pick up the slack.

In general, the technical risk for ALMA is manageable. Particularly so, if the Project will bear in mind the guidance of the AMAC and focus on achieving the specifications.

4. A Risk Mitigation Approach to Antenna Procurement

As noted above, the high risk areas for the ALMA antenna procurement are cost and schedule. I recommend that we adopt a procurement strategy that simplifies the contracting; provides to us a mechanism to maintain the Project schedule—in particular to assure that the first antenna arrives in Chile in October 2005—and confines whatever cost risk is associated with the "Japan factor" to NAOJ. We do all of this at the expense of increasing the technical risk to a quantifiable extent. Specifically, I recommend that we adopt the follow approach.

Recommendation #1: We confirm our agreement as to the specifications of the ALMA 12-meter antennas. These specifications are given in detail in the contracts for the

VertexRSI and the EIE ALMA prototype antennas. They are supplemented by ICDs that have been provided to the antenna vendors.

Recommendation #2: We agree that North America and Europe will contract for, and pay for, 42 of the ALMA 12-meter antennas built to those specifications from a single vendor to that vendor's design. Similarly we agree that NAOJ will provide, at NAOJ expense, 22 of the ALMA 12-meter antennas also built to those specifications from a vendor of NAOJ's choosing and to that vendor's design. Finally, we agree that the "value" to the Project of each antenna will be computed as the fractions 21/42, 21/42, and 22/42 of the cost of the North America-Europe antenna contract for North America, Europe and Japan respectively. This creates an ALMA array of antennas of two different designs, but the antennas meet the same technical specifications (their differences on the imaging performance of ALMA can be simulated and quantified).

Recommendation #3: As required by the prototype antenna contract, we ask AUI/NRAO to request from VertexRSI a firm, fixed price quote for a production quantity of 42 antennas built in a way that assigns value for half the work to European contractors and half the work to contractors in North America.   On the current schedule the request to VertexRSI would be made in May 2002.

Recommendation #4: We define a testing program for the VertexRSI antenna that involves only single dish tests and that will allow us to establish whether this antenna does indeed meet the ALMA specifications. Holographic surface measurements are included.

- This increases the technical risk. Interferometric measurements provide a more discriminating test of the antenna performance.
- Using the schedule in Table 1, these tests end nine months after the antenna is delivered to the VLA ALMA test site. For a 23 April 2002 delivery the testing program could conclude February 2003.

Recommendation #5: If the VertexRSI antenna is demonstrated to meet the specifications we initiate immediately the procurement process for the 42 antennas to be provided by Europe and North America. Again referring to the schedule in Table 1, this would have the first production antenna delivered to Chile 25 months later, in March 2005. This will give us 6 months slack in the antenna schedule.

Recommendation #6: We consider the ramifications of terminating the contract for the EIE antenna. Terminating the contract will increase the technical risk because we will be dependent on the VertexRSI antenna to meet the ALMA specifications. It may increase the cost risk as VertexRSI will understand that the only competition comes from the NAOJ prototype. On the other hand, there is still the incentive to VertexRSI to provide a competitive price because they can "lock up" the contract early thereby pre-empting us from seeking alternative sources (since we own "their" design).

Recommendation #7: NAOJ must still provide their prototype antenna to the ALMA VLA test site. It must also be confirmed through tests to meet the ALMA specifications.

Once it does, NAOJ should be encouraged to contract for a production quantity of 22. The “parts list” from VertexRSI will be provided to the NAOJ contractor so that he can use as many common parts as possible in his design.

Recommendation #8: The test interferometer made up from the VertexRSI antenna and the NAOJ antenna remains an important part of the ALMA verification process and must be completed. It will be used to verify prototype ALMA hardware before production fabrication is initiated; it will be used to test the ALMA software system; and it will provide a training environment for the staff members who will work in Chile.

At this time I believe it is to our advantage to mitigate schedule and cost risk, which I believe are substantial, at the expense of some technical risk which I believe to be only modest. There are operating costs to consider also—the cost of stocking spares for two different antennas—but that cost can both be minimized (sharing the VertexRSI parts list early with NAOJ) and controlled by careful structuring of the antenna ICDs.