SMA: Anatomy of a Project

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An after-dinner talk is supposed to be entertaining and funny. Alas, this one is short on humor and long on history. I had a hard time recalling the funny incidents. I could better remember the difficult and awkward moments.

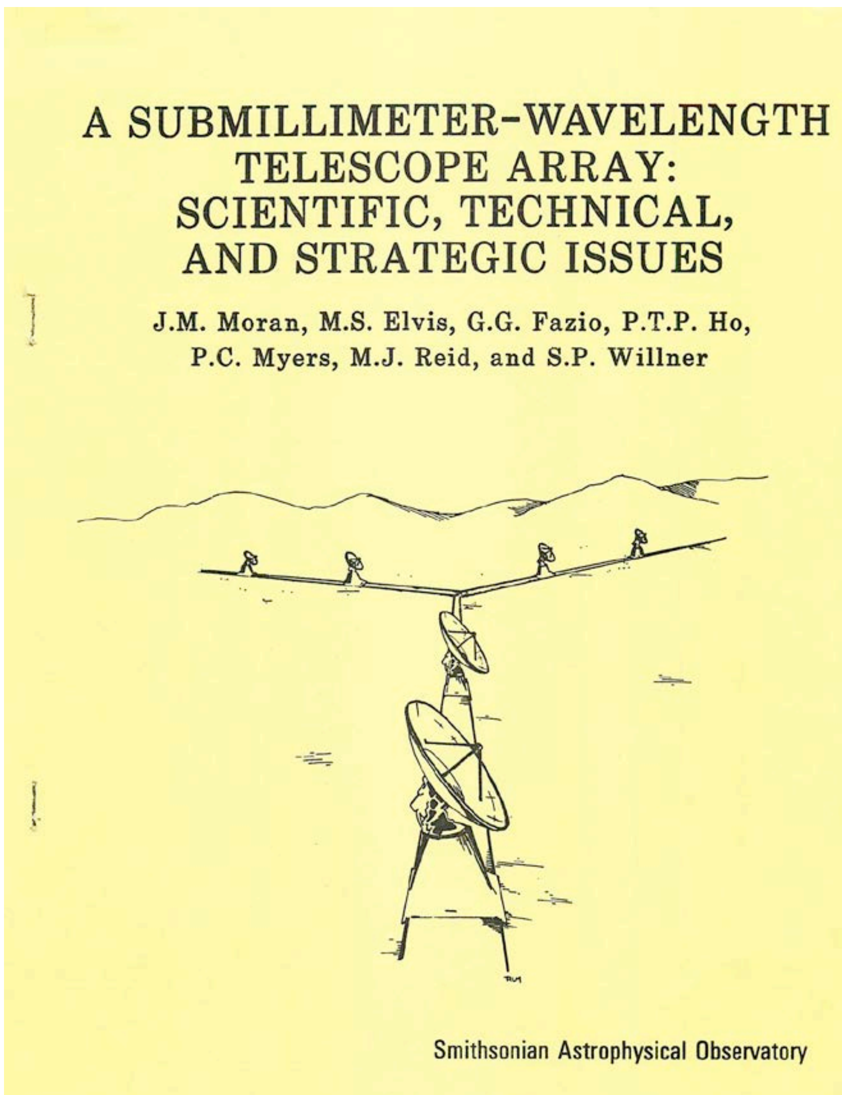
I'll start at the effective beginning. When I arrived at the CfA as director, I talked with many people and then considered an instrumental theme: interferometry at all feasible wavelengths. Since microwave interferometry was at that time well established, I thought of pushing the boundaries to submillimeter, infrared, optical, and (in unrealistic dreams of space) ultraviolet and X-ray wavelengths.

Submillimeter astronomy was then just opening up for single-dish research. The University of Arizona and the Max-Planck Institute for Radio Astronomy in Germany were engaged in building a 10-meter-diameter submillimeter dish to be erected in the southwestern United States. Caltech was also building a 10-meter-diameter submillimeter telescope on Mauna Kea, and plans were under way to build an international consortium's 15-meter-diameter ("James Clerk Maxwell") single submillimeter telescope there as well. My mind naturally turned to the possibility of building a two-element interferometer in conjunction with the University of Arizona–Max-Planck group, given our already long-standing collaboration with the University in the Multiple Mirror Telescope (MMT). Thus, in July 1983, I formed a committee at the CfA, with Jim Moran as chair, and with other members being, in alphabetical order (as always here), Martin Elvis, Giovanni Fazio, Paul Ho, Phil Myers, Mark Reid, and Steve Willner. All members are still active at the CfA and/or the SMA. This committee completed its work in about one year, handing me a very thorough analysis of the possibilities, and containing a proposal to build a free-standing six-element array of 6-meter-diameter dishes. There was only one small problem: The estimated cost was $25 million on a continental U.S. site, about two and a half times what I had thought I might conceivably be able to raise. I remember gulping and deciding, "Okay; I'll try to raise it." There was, of course, a slight other potential budget problem. The submillimeter weather was far better on the top of Mauna Kea in Hawaii than it was any place in Arizona. But it wasn't an even trade; because of its location in the middle of the Pacific (roughly speaking), a later report (the official Design Study of 1990) estimated the cost at nearly twice as much were the array placed on Mauna Kea than in Arizona, i.e., about $45 million. As it turned out, for a variety of reasons, that was an underestimate by about a factor of two.

Now we move to the anatomy of the project, starting at the beginning: no money. What to do? I hit on an intriguing idea, or at least I thought it was so. I would try to start a new line item in the Smithsonian federal budget, which we would call the "major scientific instrumentation" (MSI) line item. MSI funds would be "no year" funds. That is, they would be available until expended; they would not have to be spent by the end of each fiscal year or be lost, as would regularly appropriated federal funds. (The "lost alternative" would likely mean that funds could not be expended with optimum efficiency.) This was the principle of the MSI line item.

How to create it in practice? The way to plant the seeds, I thought, was to bring up the idea of the SMA and the MSI means to fund it through discussion with the then secretary of the Smithsonian Institution, S. Dillon Ripley, a distinguished ornithologist previously at Yale. I would speak with him before the annual budget meeting between the Smithsonian and the Subcommittee, chaired by the Democrat Sidney R. Yates of Chicago, of the House Appropriations Committee that deals with the Smithsonian's federal budget.

As to the budget-buildup stage: In preparation for the spring 1984 meeting of Yates's committee, I decided to bring with me to Washington a drawing of the array, for visual effect. Since my talents in that direction are very conspicuously absent, I discussed with my son, Steven, the possibility of his classmate at Lexington High School, Bob Marvin, drawing a picture, in living color, of the array – or at least an attractive idealization of such. I came to the luncheon for those who were going to be at the afternoon meeting of the House Subcommittee with the drawing rolled up in a tube. I walked into the luncheon with Ripley and sat next to him for the meal. During its course, I discussed the idea for the array with him, noting how it would be a pioneering instrument and unsheathing the picture Marvin had drawn. (See a copy of the cover of the CfA committee's final report, which came out in July 1984 and is adorned with this picture.) This was to be Ripley's last hearing as secretary of the Smithsonian Institution and, I suspect, he wanted to go out in spectacular fashion. The submillimeter array, pioneering in astronomy a new region of frequency space, seemed to fit this idea quite well. To start the ball rolling, I decided to offer to Ripley, and he to pass on to Yates, the possibility of transferring $525,000 from the SAO budget to the MSI line item that I proposed. My guess is that Yates considered that I could give as well as take, and was not, as most were, mostly or all take. This thought had not struck me earlier, but it may well have been correct.



In the years following this first presentation of the idea, which was accepted in the federal budget, the amount of money in the MSI line item mounted rather rapidly (see below). I soon decided to use it simultaneously for two projects: the Submillimeter Array as originally proposed, of course, as well as the change of the MMT into a large, single-mirror telescope, 6.5 meters in diameter. This second project was in partnership with the University of Arizona: they brought Roger Angel's ideas on spin-casting and polishing large mirrors and in-kind contributions. We supplied the needed mechanical work, new instruments, and money. In those days, getting cash contributions from Peter Strittmatter, the charismatic then director of the Steward Observatory, was virtually impossible. So we made this agreement, which kept the University's Mirror Laboratory alive and gave our two institutions a far more powerful MMT.

Given that the Democrats continued to control the House and that Yates continued as chairman of the subcommittee dealing with the Smithsonian budget, we maintained a steady upward path for the amount of funds placed in the MSI line item until nearly the mid-1990s, when we reached an annual total of $8 million in this account.

Despite, or perhaps because of, this build-up, the many people who wished to attack the budget homed in first on the "no-year" aspect of the MSI line item. That flexibility, in effect, soon—within a few years—disappeared from our firmament.

Those who were around then will remember that the Democrats lost control of the House to the Republican Party in 1994. At that point, alas, the knives of Congressional budget cutters emerged and this time started cutting into the MSI line item itself and over the next ten years reduced it by nearly half. Little remains sacrosanct for long in Washington. The MSI account was certainly not one of those exceptions, despite our valiant attempts to preserve it.

As another side note: NRAO was at this time pushing a millimeter array as its next big project, following the cancellation of its single, 25-meter-diameter, millimeter-wave telescope project. In partial response to that push from NRAO, Eric Bloch, then the Director of the National Science Foundation, invited several NRAO staff members, including the then NRAO Director, Paul Vanden Bout, as well as Phil Myers and me from SAO, to give him a presentation in his office. This meeting took place in September 1988, according to Phil Myers's contemporaneous notes. During the course of this general discussion, Bloch asked me how we were funding our Submillimeter Array. I explained my procedure, which was by then assured of advancing since it had well over $1 million per year slated for this line item for FY1989. Bloch immediately jumped on this MSI idea and proclaimed that he would adopt that method for funding major research instrumentation at the NSF. This he did, forthwith, as I later tracked down with the historian of the NSF, who was able to pinpoint Bloch's suggesting this approach to just the time that we had met in his office and I had told him about this funding idea. I can thus conclude with confidence that the funding of LIGO as well as of the U.S.'s part of ALMA can trace its roots to SAO's Submillimeter Array.

Back to the SMA ranch: Money was of course a vital prerequisite. But we needed talented people as well as funds. Not so easy to come by. Jim Moran, then the associate director for the Radio and Geoastronomy Division at the CfA, took on the hiring job, or at least a large brunt of it. Obtaining a project director turned out not to be so easily done; after a search stretching over a year or so, we finally hired as the project director Eric Silverberg; he had been the project director for the successful lunar-laser ranging project. Eric then hired Bill Bruckman as the lead mechanical engineer.

Somewhat earlier, we were very lucky in being able to hire Colin Masson from Caltech's Owens Valley Radio Observatory. Colin designed the detailed signal processing for the array, a large and intricate assignment, before leaving for better financial climes at Renaissance Technologies. We had already been concentrating for some time on trying to hire a leader for the receiver effort for the array—a key, if not the key, ingredient to the entire plan. We were profoundly fortunate to succeed in attracting Ray Blundell from IRAM to the project.

All four people were hired within about a 12-month period.

In addition, we got a superb group of people from around the world to agree to advise the project as the plans for the SMA were developed. These were Roy Booth, Reinhard Genzel, Roger Hildebrand, Richard Hills, Bill Hoffman, Masato Ishiguro, Tony Kerr, Peter Napier, Tom Phillips, Ian Robson, Nick Scoville, Paul Vanden Bout, Jack Welch, Gisbert Winnewisser, Dave Woody, and Gareth Wynn-Williams.

Not only was Ray key to the receiver effort, but he was, as it turned out, also key to our successfully building the array elements themselves. Eric and Bill had put forth a mechanical design for each array element, which did not contain a counterweight. This design was certainly novel but also quite risky: Pointing would require greater (hence less reliable) corrections; a brake failure in slewing the antenna would much more likely be catastrophic; and, in addition, there would be the question about how the antenna would behave during unusually high winds. Our advisory committee warned sharply against our implementing this plan, urging us instead to go the more conservative path of counterweights. To make the proverbial long story shorter, by 1994 it was clear that project management changes were needed, so we made changes at the top. I appointed Jim Moran as project director, and he asked Ray to take on the additional responsibility for the antenna group and George Nystrom to be its chief mechanical engineer. They filled in admirably for Bill Bruckman, in taking on the antenna design and construction.

The aluminum panels for the antenna surfaces were made by the Bosma Construction Co., in Dayton, Ohio, and were each machined to match its part of a parabola of revolution to within about 5 μ RMS, a tour de force resulting in our meeting the 12 μ RMS specifications over the whole antenna area of 72 panels.

Thanks to our friends at the Haystack Observatory, we were given (previously vacant) space at their site in Westford, Massachusetts, to erect a construction building, outside of which we could move and test the completed antenna systems. This antenna site enabled us to bring each of the antenna systems up to snuff before shipping it to Hawaii for erection on Mauna Kea.

Meanwhile, very shortly after he joined the SMA project, Ray hired Ed Tong to take on the main part of the job of building the receiver elements for each of the frequencies to be used with the array. We started with 250 and 350 GHz receivers, before moving on to 450 and 650 GHz receivers. Some of the other fabulous members of Ray's receiver group that come to mind are Jack Barrett, an electrical technician; Louie Lambruno, who did a brilliant job designing the cryogenics package for the receivers; Cosmo Papa, who's still going strong as a mechanical-design genius even though he cut his teeth rather long ago as a technician at MIT during the waning days of WWII; and Michael Smith, a superb machinist.

We also hired many additional people, each truly first rate, who helped with all the different aspects of the design, construction, and test phases for the array, including Matt Dexter; Mark Gurwell; Eric Keto, who invented the Reuleaux triangle antenna layout; Steve Leiker; Nimesh Patel; Philippe Raffin; TK Sridharan; Tony Stark; John Test; Bob Wilson, whose deep and broad technical knowledge, coupled with his calm nature and unsurpassable integrity, made an enormous contribution to the successful completion of the SMA; Ken ("Taco") Young; Qizhou Zhang; and Jun-Hui Zhao.

Near the end of the construction phase, we built a base camp close to sea level in Hilo, Hawaii. Before that time, in 1996, we had reached agreement with the Academia Sinica Institute of Astronomy and Astrophysics (ASIAA) in Taiwan, partly through the initiative of Typhoon Lee, an early director there, and with strong intermediary and later support from Paul Ho, to expand the array to eight elements, with the last two being provided solely by ASIAA. This collaboration has worked out very well and has had many mutual benefits. Beyond yielding a larger array, the back-up structure for each element of the array benefitted from carbon-fiber tubes manufactured by a firm in Taiwan.

Moving the antennas from Massachusetts to the peak of Mauna Kea was a logistical headache. Each antenna made its way by truck to Seattle, barge to Honolulu on the island of Oahu, interisland barge to Kawaihae Harbor on the island of Hawaii, and truck to the summit of Mauna Kea—a total trip of about three months. In 1996, Ant Schinckel joined the SMA team and was an excellent site/construction manager on Mauna Kea and, although no longer with the SMA, came from Australia to celebrate this tenth anniversary occasion with us.

A word on data: We also made a big investment in data processing for both the raw signals and the scientific products. As for most software projects, these took far more time than originally expected, but the product has been serving us robustly ever since, with enormous thanks to Taco.

I will come very close to the end with a brief description of the groundbreaking for the array, which took place in early June 1995. Despite my not being exactly fond of flying, I undertook to attend the groundbreaking ceremony. I flew outward bound about 5,000 miles, almost getting there. But the rest of the trip proved beyond my grasp. I got up to the intermediate-level camp at the 9,000-foot-altitude level on Mauna Kea, where we stopped for lunch. Wandering around, I happened on a pool table. It was set up with the white ball arranged such that a combination shot was possible: the white ball into a colored ball into another colored ball, with the last then dropping in the back pocket. It was too much of a temptation to resist. So I attempted it. To my utter amazement, the second colored ball dropped in the pocket. I became very excited, telling people about this unusual event—at least for me. I became sufficiently animated that I developed a slight headache. The accompanying medical officer advised that I remain behind and not go to the summit for the groundbreaking event. Thus, I had traveled the whole way but failed to gain permission to go the final vertical mile. Instead, I cooled my heels for several hours at the 9,000-foot level. I did not even get to watch the proceedings on TV at that time. If you wish, you may still shed a few crocodile tears for me.

Eight-plus years later, after the array and the base camp were completed, the SMA was dedicated in a ceremony also minus my physical presence. Ten years beyond that brings us to this evening and this brief review of the history of the Submillimeter Array, which still has much life left in it. And I look forward to enjoying its further scientific triumphs and maybe to another such colloquium.