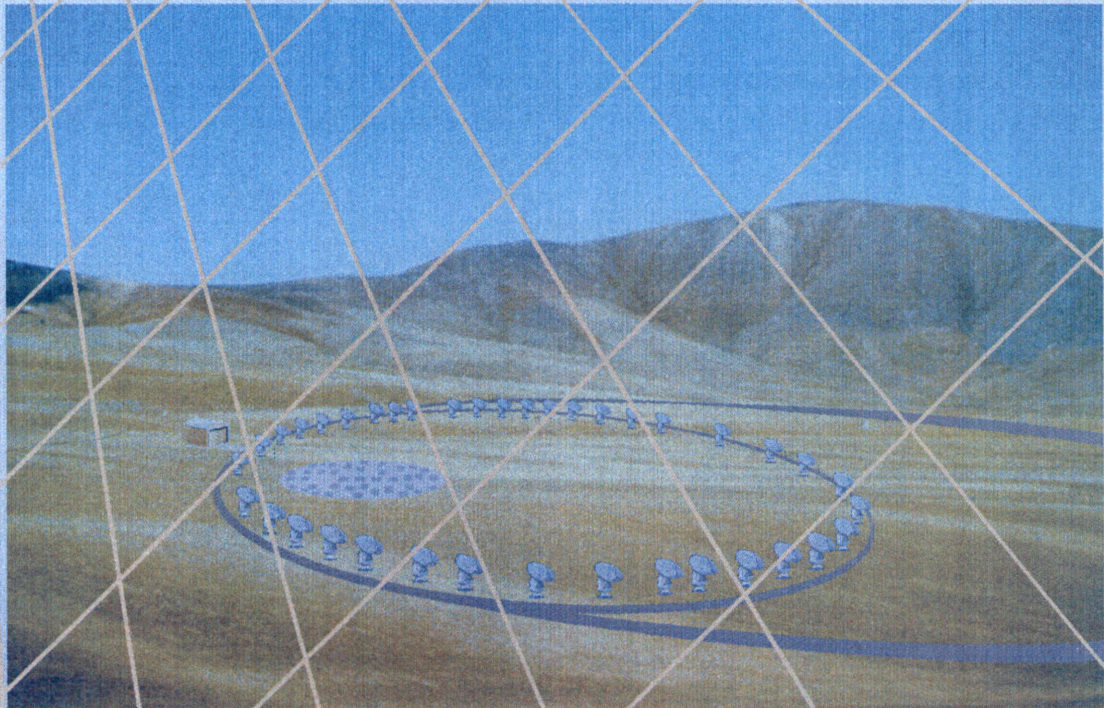


Millimeter Array

Construction Cost of the
U.S. Reference Project

May 1999



NATIONAL RADIO ASTRONOMY OBSERVATORY

A facility of the National Science Foundation operated under
cooperative agreement by Associated Universities, Inc.

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EXECUTIVE SUMMARY

The Millimeter Array (MMA) will provide new and uniquely important capabilities for observational astronomy in the next century. It will extend the powerful, high-resolution imaging techniques of radio astronomy to millimeter wavelengths, where cosmic thermal objects illuminate the sky. The vast discovery space opened by the MMA for scientific inquiry has attracted so much attention from scientific communities in Europe and Asia that an enhancement of the project through international partnership is now being negotiated. A clear understanding of the cost basis for the joint project is a necessary input to these negotiations. The MMA project is sufficiently advanced that it can be used to provide the baseline cost; that is the purpose of this analysis of the MMA construction cost.

The MMA Project has nearly completed the first year of a three year Design and Development phase. In that year the technical description of the project has become sufficiently advanced that it is possible to construct a complete system diagram for the array and, using that system description, to create a work breakdown structure for the array construction project. This is the approach taken here. However, in the decade since the MMA proposal was submitted by Associated Universities, Inc., (AUI) to the National Science Foundation (NSF) the MMA concept has evolved in response to new scientific opportunities opened by the high atmospheric transparency of the superb Chilean site chosen for the MMA and in response to the scientific emphasis, and resources, potentially brought to the project by international partners. Since it is not possible to cost an evolving project we have chosen to identify a MMA made up of antennas of 10 meters diameter that meets the scientific specifications proposed for it by AUI and we will cost it. We call that array the MMA U.S. Reference Project.

The construction cost of the MMA U.S. Reference Project is derived from the construction WBS created in anticipation of the more ambitious, joint U.S.-European project. We establish the MMA U.S. Reference Project cost by making adjustments, where needed, to make the costed array consistent with the requirements of the U.S. Reference Project. Additions made to the scope of the U.S. Reference Project for the needs of the U.S.-European project are accumulated as scope adjustments so that they can be included, as desired, in the partnership negotiations. It is further assumed that an operations budget for the project begins as soon as hardware exists to be operated. These operations costs also are accumulated separate from construction costs.

Construction occurs over the seven years 2001-2007. In 2001 dollars the cost of the MMA U.S. Reference Project is \$240M to which \$52M in contingency should be added. In current year dollars these costs become \$257M and \$57M, respectively.

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I. THE MILLIMETER ARRAY PROJECT

1.1 Science Objectives

The Millimeter Array (MMA) Project will provide scientists with an instrument uniquely capable of producing detailed images of the formation of galaxies, stars, planets and of the chemical precursors necessary for life itself. The MMA is a radio telescope. It is designed to operate at wavelengths of 0.4 to 9 millimeters where the Earth's atmosphere is partially transparent and where clouds of cold gas as close as the nearest stars and as distant as the observable bounds of the universe all have their characteristic spectral signatures. It will image stars and planets being formed in gas clouds near the sun, and it will observe galaxies in their formative stages at the edge of the universe which we see as they were nearly 10 billion years ago. The Millimeter Array provides a window on celestial origins that encompasses fully both space and time.

The Millimeter Array is a synthesis telescope. It consists of more than 30 precision antennas all operating in concert to provide the imaging capability of a single antenna more than 3000 meters in diameter. The signals received by the superconducting receivers on each antenna are digitized and processed in a special purpose computer or signal correlator. Images of astronomical objects and cosmic phenomena are made using computer algorithms designed to correct for atmospheric propagation effects and for the fact that the *synthesized* telescope is in fact made up of individual, separated, antenna elements. The image-forming *optics* of the MMA is a computer.

By extending the high-resolution imaging techniques of radio astronomy to millimeter wavelengths the MMA will achieve an astronomical imaging capability equal in clarity of detail to the imaging capability of the Hubble Space Telescope (HST), but it will do so at wavelengths where the richness of the sky is provided by thermal emission from the cool gas and dust from which all cosmic objects form. The MMA is the appropriate scientific complement to the HST, and its successor instrument the Next Generation Space Telescope (NGST). Such high resolution imaging comes from observations made with the MMA antennas arranged in its most extended configuration. Lower resolution imaging of large areas on the sky is achieved by a compact configuration in which all the antennas are placed very close to one another. This *reconfigurability* gives the MMA a *zoom-lens* capability which allows scientists to tailor the imaging capabilities of the instrument to the astronomical object under study. Uniquely, the MMA is a complete imaging telescope.

The unprecedented MMA combination of sensitivity, angular resolution and imaging fidelity at the shortest radio wavelengths for which the Earth's atmosphere is transparent provide a wealth of new scientific opportunities; scientists using the MMA will:

- Image the redshifted dust continuum emission from evolving galaxies at epochs of formation as early as $z=10$;
- Determine through molecular and atomic spectroscopic observations the chemical composition of star-forming gas in the earliest forming galaxies;
- Reveal the kinematics of obscured galactic nuclei and Quasi-Stellar Objects on spatial scales smaller than 300 light-years;
- Assess the influence that chemical and isotopic gradients in galactic disks have on the formation of spiral structure;

- Image gas-rich, heavily obscured regions that are spawning protostars, protoplanets and pre-planetary disks;
- Determine the temperature of the photosphere of thousands of nearby stars in every part of the Hertzsprung-Russell diagram;
- Reveal the crucial isotopic and chemical gradients within circumstellar shells that reflect the chronology of invisible stellar nuclear processing;
- Obtain unobscured, sub-arcsecond images of cometary nuclei, hundreds of asteroids, *Centaurs*, and Kuiper-belt objects in the solar system along with images of the planets and their satellites—observations that can be done for astrometric or astronomical purposes during daylight or nighttime hours;
- Image solar active regions and investigate the physics of particle acceleration on the surface of the sun.

The MMA is conceived and designed to be a long-lived user observatory. Its scientific impact at any time will be facilitated by the quality of its instruments and limited only by the creativity and industry of its scientist-users.

A concise summary of the technical specifications of the MMA is given in Table 1.1.

Table 1.1 Summary of MMA Specifications

Array

Number of Antennas	> 30
Total Collecting Area	> 2500 m ²
Angular Resolution	0".07 λ (mm)

Configuration

Compact:	70 m
Intermediate (2)	250 m, 900 m
High Resolution	3000 m

Antennas

Diameter	12 m
Precision	< 25 micrometers RSS
Pointing Precision	0".8 RSS
Fast Switching	Cycle < 10 seconds
Total Power	Instrumented
Transportable	By vehicle with rubber tires, on roads

Receivers

28 - 45 GHz HFET	T(Rx) < 20 K
67 - 95 GHz HFET	T(Rx) < 40 K
91 - 119 GHz HFET or SIS	T(Rx) < 50 K
125 - 163 GHz SIS	T(Rx) < $6 \cdot h \cdot \nu / k$ SSB

163 - 211 GHz SIS	$T(Rx) < 6 \cdot h \cdot \nu / k$ SSB
211 - 275 GHz SIS	$T(Rx) < 6 \cdot h \cdot \nu / k$ SSB
275 - 370 GHz SIS	$T(Rx) < 6 \cdot h \cdot \nu / k$ SSB
385 - 500 GHz SIS	$T(Rx) < 6 \cdot h \cdot \nu / k$ SSB
602 - 720 GHz SIS	$T(Rx) < 8 \cdot h \cdot \nu / k$ SSB
Dual Polarization	All receivers

SIS Mixers

Image Separating	All SIS frequency bands
Balanced	All SIS frequency bands
Integrated with IF amplifier	All SIS frequency bands

Intermediate Frequency (IF)

Bandwidth	8 GHz, each polarization
-----------	--------------------------

Correlator

Baselines	> 600
Bandwidth	16 GHz per baseline
Spectral Channels	4096 per IF

1.2 Project Development

Planning for the Millimeter Array began at the National Radio Astronomy Observatory (NRAO) in 1982. A series of community science workshops sponsored by the NRAO were held in the decade of the 1980s that served to define the scientific requirements and technical specifications for the MMA. The result of these workshops became the basis for the MMA Proposal¹ submitted by Associated Universities, Inc., to the NSF for the design, construction and operation of the MMA. AUI is the contractor that operates the NRAO under Cooperative Agreement² with the NSF.

The Millimeter Array Project proposed by AUI in 1990 was an array of 40 antennas each of 8 meters diameter equipped with receivers covering all the atmospheric windows at millimeter wavelengths, specifically to a highest frequency of 350 GHz. The MMA proposed then was optimized for precision imaging which is achieved by having a sufficient number of antennas—or more precisely, a sufficient number of interferometers, pairs of antennas—to fill the uv-plane quickly and completely. The figure of merit for precision interferometric imaging is ND , the product of the number of antennas in the interferometric array, N , and their diameter D . For the MMA proposed by AUI in 1990 this figure of merit, $ND = 320$.

¹*The Millimeter Array*, proposal submitted to the National Science Foundation by Associated Universities, Inc., July 1990.

²Cooperative Agreement No. AST9223814 between the National Science Foundation, Arlington, VA 22230 and Associated Universities, Inc., Washington, D.C. 20036.

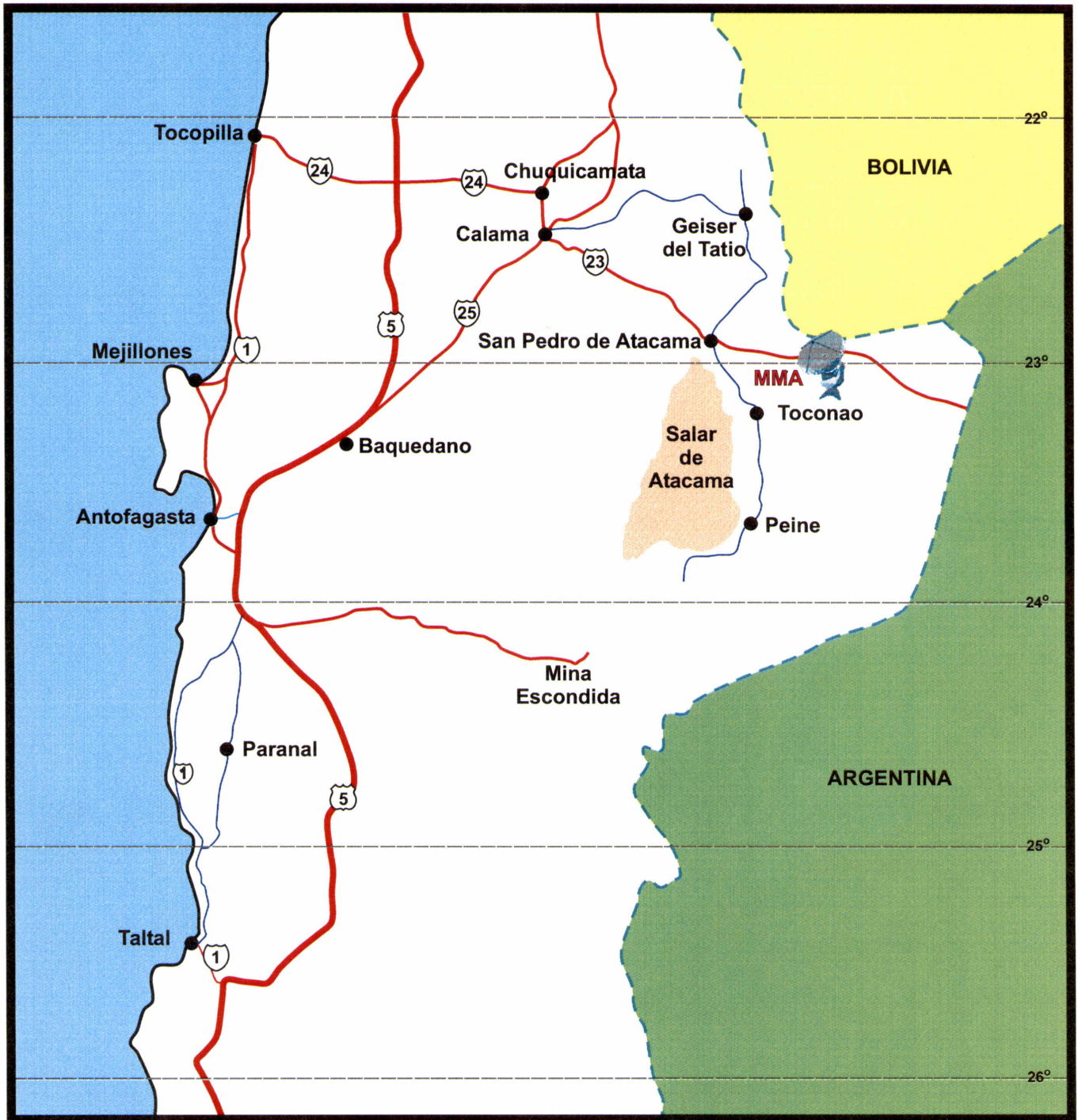
Identifying a suitable site for the MMA was a major undertaking that occupied the decade 1985 to 1995. Remotely operated atmospheric testing equipment was built and operated at four potential MMA sites. These sites were: the Magdalena mountains near Socorro, NM; the White Mountains near Springerville, AZ; Mauna Kea on the island of Hawaii; and the Altiplano in northern Chile. The testing equipment continuously monitored the atmospheric transparency of the site and provided meteorological data. Summer incursions of moist gulf air make the sites in the continental United States unusable for the scientific objectives of the MMA many months of each year. The site in Hawaii is greatly superior to the continental U.S. because the steady trade winds maintain a nearly constant climate year round. But the flat area required for the MMA is not available on Mauna Kea. The identification of a truly excellent, and large site in the Chilean Altiplano proved ideal for the MMA and led to its recommendation to the NSF³. A map of northern Chile showing location of the site is presented on the following page.

The exceptionally dry conditions on the Chilean site meant that the sensitivity of the MMA would not be limited by atmospheric emission and that the full scientific gain of quantum limited receivers could be realized on that site. It also meant that the submillimeter atmospheric windows were also transparent from that site, unlike the case for the other potential sites studied for the MMA. Recognizing this, the scientific Millimeter Array Advisory Committee (MAC) recommended in 1995 that an observing capability in at least one of the submillimeter windows become part of the baseline MMA project. That committee report is available on the web at <http://www.mma.nrao.edu/committees/>. This recommendation is an addition to the scope of the array proposed by AUI, but it is also extremely desirable scientifically and exploits fully the potential of the site.

The scientific excitement of the MMA, and the excellent observing conditions provided by the Chile site, galvanized interest in Europe and led to the definition of a project similar in scientific scope to the MMA called the Large Southern Array (LSA). In 1997 representatives of the MMA and LSA project teams met and agreed on the desirability of merging these two projects into a single project of larger scope. The merged project was to emphasize both the precision imaging requirement of the U.S. scientists with the requirement of the European group for spectroscopic imaging of molecular gas in cosmologically-distant galaxies. The latter scientific requirement has as its figure of merit the product ND^2 and, for fixed cost, favors an array of a small number of large antennas: the European group favored antennas of 15-16 meters diameter. Clearly, to merge the two projects a compromise is required on the antenna diameter between the 8 meters proposed by the U.S. group and the 15-16 meters favored by the Europeans. While this discussion was in progress the MMA scientific advisory committee, the MAC, encouraged the MMA Project to focus design studies on an antenna larger than 8m in hopes of securing the merger by compromising with the European project. This recommendation from the 1997 MAC meeting is also available on the web at the same URL as noted above. The MMA Project heeded this recommendation and began work on an antenna design of 10 meters diameter that maintained its performance in the submillimeter.

The change in antenna diameter to 10 meters would not compromise the imaging performance emphasized by the U.S. community in the design of the MMA so long as the imaging figure of merit, ND was not diminished by that change. To preserve the $ND=320$ proposed by AUI to NSF for the MMA meant that the U.S. Reference Project should have 32 antennas in the array if it is to be composed of 10m diameter antennas. However, a figure of 36 antennas was used as a way of assuring that the minimal imaging requirements of the MMA could be preserved even in the event that the performance of a 10m antenna, as

³*Recommended Site for the Millimeter Array*, submitted by Associated Universities, Inc., to the NSF May 1998.



built, may not be equal to that of an as-built antenna of 8m diameter. The increase from 32 antennas to 36 antennas is an increase in scope to the U.S. Reference Project beyond that proposed to the NSF.

Currently (May 1999) the NSF is negotiating with a confederation of European organizations to subsume both the MMA and the LSA into a joint, international project called the Atacama Large Millimeter Array (ALMA). The goal is an array of 64 antennas of 12 meters diameter.

II. REALIZATION OF THE MMA IN TWO PHASES

2.1 Introduction

Recognizing that the scale of the Millimeter Array set it apart from many NSF initiatives and projects, the NSF and AUI agreed that it was desirable to structure the MMA project in two phases: A design and development, or prototyping, phase to be followed by review and separate approval for the construction phase. Discussions toward the implementation of this process have been underway since 1992; funding for the design and development work began in 1998.

2.2 MMA Design and Development Project

The MMA Design and Development (D&D) Project began with FY1998 funding in June 1998. It is a three-year project that will conclude with the initiation of MMA construction in 2001. The major goals and deliverables of the MMA Design and Development Project are:

1. The complete MMA system diagram at the module level including
 - Engineering analysis of design alternatives
 - Design decisions for both hardware and software
 - Working prototypes of key instrument modules
 - Prototype of the array antenna
2. The construction phase work breakdown structure used as the basis for the array construction cost estimate;
3. A recommendation for an international partnership in the project;
4. Identification of a site for the array and permission for its use.

Engineering and design work being done as part of the D&D to construct the complete array system diagram is detailed in the MMA Project Book⁴. The cost estimate given here is based on the baseline MMA as described in the Project Book. As a result of the design decisions noted in the Project Book the final design of the instrument to be built will change from the baseline. Nevertheless, the baseline project at the present time is sufficiently complete that it is possible to create a WBS for the construction phase of the project and to cost that baseline. That is the intent of this document. At the conclusion of the D&D work the cost estimate will be refined.

2.3 MMA Construction Project

MMA construction will begin in 2001 upon completion of the design and development phase of the project. An abbreviated, but otherwise complete, WBS for the construction phase of the U.S. Reference Project is attached. The overall structure of the project is unlikely to change even as the project is done as a joint international project.

⁴*Millimeter Array Project Book*, v2.5, ed. D. Emerson, May 1999.

The overseas site for the MMA creates the need to organize the construction project around integration facilities in the U.S., and to ship to the site only completed, functioning, and tested hardware. This is to minimize costly overseas construction staff. For the MMA construction project the initial system integration, and all the testing and evaluation of the prototype antennas, will be done at the NRAO VLA site where office/laboratory facilities and crafts specialists are available. The first two years of the construction project will emphasize development of the site civil works in Chile. This includes not only construction on the array site of the roads, power generation and distribution system and buildings, but it also includes construction of the Operations Support Facility (OSF) in the nearby village of San Pedro de Atacama. Only in the third year of the MMA construction project is the contract let for the production suite of antennas. Once the first antennas arrive in Chile the system integration task will relocate to Chile. One important part of the system integration is testing and commissioning of the newly arriving hardware. That will be done by involving the U.S. scientific community in the testing process of the array; a process that will gradually and naturally evolve into interim scientific operations of the MMA.

III. COST ESTIMATE FOR MMA CONSTRUCTION

3.1 Basis of the Estimate

The cost basis for the MMA U.S. Reference Project is predicated on the following:

1. The MMA U.S. Reference Project is an array of antennas of 10 meters diameter that meets the scientific objectives incorporated in the 1990 AUI proposal for the MMA;
2. The MMA Design and Development Project is carried to a successful completion;
3. The construction project follows with no interruption from the D&D project;
4. MMA interim operation begins with operation of the test interferometer used to evaluate the prototype antennas and with initiation of site work in Chile.

Point (1) warrants explanation. As described in section 1.2 above, the MMA project has evolved since the AUI proposal in 1990 in many extremely positive ways. Most particularly, the evolution was motivated by scientific opportunity unappreciated at the time the AUI proposal was submitted and by political opportunity to merge the MMA into an international project of truly major scope. The former consideration led to an increase in scope to the MMA by the addition of a capability for submillimeter observations. The latter led to a reconsideration of the optimum antenna diameter for a large-scale international project that caused the MMA baseline antenna diameter to evolve first to 10 meters and later to the 12 meters adopted as the baseline by the joint NSF-European negotiators. One can present a cost estimate by fixing the array parameters and that is one approach followed here. On the other hand, there is great interest in using the effort that has gone into producing this cost estimate to cost augmentations to the MMA and to cost the joint ALMA construction project. For these reasons the cost estimates below include handles to attach calculated costs for a variety of augmentations to the MMA U.S. Reference Project.

The MMA U.S. Reference Project costed here is this: 32 antennas of 10 meters diameter built at the Chajnantor site in the Altiplano of northern Chile; the array has receivers covering the atmospheric windows at millimeter wavelengths (through 370 GHz) but no submillimeter capability; the largest array configuration is a circle 3 km in diameter.

Options are included in the costing for an array of 36 10 meter diameter antennas that has been discussed with the NSB; options are also included for including submillimeter capability to the array; and for both of these things to be included.

3.2 Construction Work Breakdown Structure

The WBS for the construction phase of the MMA U.S. Reference Project is included here as Appendix A. It is based on the WBS for the MMA Design and Development phase and is regarded as an extension of that project. It lists specifically the steps taken to procure and outfit each antenna individually. This is more detail for the antenna task than is needed for a cost estimate but it is useful to have this displayed explicitly as an illustration of the pacing task of the project—it gives a tangible way to illustrate the schedule on which instrumentation modules must be available in Chile.

3.3 Cost Tables

The construction cost tables for the MMA U.S. Reference Project are included as Appendix B. A table summarizing the entire project construction cost, the sum of costs over years 2001-2007, is followed by individual tables for each of these years. Each table is organized by WBS task. Background information is provided by the descriptions given in section IV below and is amplified by the MMA Project Book and the document *Estimated Site Development Costs of the MMA Project in Chile* written for the MMA Project management by M. A. Gordon, the MMA Division Head for Site Development.

The columns included in the cost tables are the following:

WBS Task: The name of the task to which costs and personnel are assigned.

Scientists: The number of work-months of time assigned to scientists. This category includes also the project management team and the business manager.

Programmers: The number of work-months of time assigned to programmers. Includes also the system administrator.

Engineers: The number of work-months of time assigned to engineers. Engineering category includes electrical, digital, mechanical and civil engineers.

Technicians: The number of work-months of time assigned to technicians. This category also includes machinists, secretarial and administrative staff in addition to electronic technicians.

Personnel Cost: The fully loaded salary and benefits of the assigned personnel based on NRAO salary scales.

Materials and Supplies: The cost of contract services, purchased equipment and instruments; and all cables, connectors and furnishings. Details can be found in the MMA Project Book.

Transfer to Operations: Costs that are involved with operating the array. This includes the cost of operating the test interferometer, training of the initial MMA Chile staff at the test array, and operation of the first generations of equipment that arrive in Chile as a way of commissioning those instruments.

Adjustments to Scope: Costs that exceed the scope of the MMA U.S. Reference Project. This includes antennas greater in number than 32 and all submillimeter capability. The construction efforts costed were initially for a 36 element array; each major hardware and civil task related to the number of antennas has been reduced in the proportion 32/36 with the difference maintained as an adjustment to the project scope.

Contingency: The contingency is assigned to each WBS costed task separately. The percentage contingency adopted for each is in accord with the following:

- 15% is assigned to all fully-loaded salaries;
- 15% is assigned to the hardware cost for all instrumentation hardware that is similar to instrumentation built previously at the NRAO; the same percentage contingency applies irrespective of whether that instrumentation is purchased or fabricated in-house;

- 20% is assigned to all civil works including buildings, roads, trenching, cabling etc;
- 30% is assigned to the hardware cost for all instrumentation hardware that is a technical extension to instrumentation built previously at the NRAO. This includes the antennas, the SIS mixers (but not the HFET amplifiers), the receiver LO, the correlator, the phase monitoring radiometer; the dual-load amplitude calibration system.

Sum Cost: The total cost of the U.S. Reference Project task-by-task. Obtained by adding the personnel cost to the materials and supplies cost and subtracting from it the transfer to operations and the adjustment to scope. Constant 2001 dollars.

Inflated Contingency: Contingency cost above inflated by 2.5% for the costs experienced in every year following year 2001.

Inflated Sum: The sum cost above inflated by 2.5% for the costs experienced in every year following year 2001.

NOTE: The amounts shown in the construction cost tables are all in thousands of dollars.

IV. DESCRIPTION OF THE COSTED WBS TASKS

1. Administration

1.1 Project Management

Includes the personnel costs, only, of the Project management team, specifically the following positions:

- Project Director
- Project Manager
- Scheduler
- Scheduling Administrative Aide
- Business Manager
- Project Scientist
- Project Secretary/Archivist
- Manager of Operations in Chile

In 2001 the Manager of Operations in Chile is transferred from construction to the MMA operations budget. In 2003 two administrative aides are added to the Chilean staff; one individual to handle business and contracts in Santiago and the other to handle imports/exports from the port of Antofagasta. See MMA Project Book chapters 16 and 17 for a description of their duties. Both these individuals work under the supervision of the Manager of Operations in Chile and both are assigned as they are hired to the operations budget.

1.1.1 Management, Planning and Oversight

A budget category used to consolidate the travel budgets of all the project staff under the supervision of the Project Manager. Costs budgeted at \$8k per project employee. Includes also travel and consulting expenses of project advisors; these latter costs supervised by the Project Director.

1.1.2 Business Operations

Includes the costs of shipping to Chile all the NRAO-provided hardware. The principal hardware to be shipped includes the receiver packages with cryogenics systems, two racks of control instrumentation per antenna, the LO reference hardware, approximately 30 racks of correlator hardware, tools, vehicles, and furnishings. All hardware will be shipped in standard ocean containers and delivered to the OSF in San Pedro de Atacama. Cost estimate based on 300 pounds per equipment rack; a total of 315,000 pounds to be shipped exclusive of vehicles.

Does not include shipping costs of the antennas. The antenna contract calls for the vendor to erect the antennas at the OSF. Does not include shipping costs of the cabling, electrical or optical fiber; these materials are included in the site development contract.

1.1.3 Chilean Operations

Office expense of Santiago and Antofagasta offices.

1.1.7 AUI Management

Annual fee for AUI Management oversight of the MMA project. Estimated. Fee to be negotiated between NSF and AUI.

1.2 Engineering

Salaries of the system engineering staff. Includes the system engineer; an aide to the system engineer who is responsible for maintenance of engineering documentation, standards, interfaces and the archive of engineering drawings; and a production engineer who is responsible for planning and engineering oversight of the fabrication of production MMA hardware, both hardware fabricated at the NRAO and that fabricated elsewhere under contract.

1.3.1 CDL Permanent Facilities

Provision for laboratory space for fabrication, testing and maintenance of the SIS mixers, the correlator and the multiplier chain local oscillator. Includes office space and an increment to machine shop space. Work to be done as part of the planned addition to the NRAO Edgemont Road Headquarters facilities in Charlottesville, Virginia.

1.3.2 Manufacturing Facilities

Assembly and test fixtures for the production hardware fabricated at the NRAO.

1.3.3 Common Infrastructure

Includes the cost of renting laboratory and office space in conjunction with the NRAO facilities in Tucson, Arizona sufficient for assembly of the receiver packages and cryogenic systems. Also includes the rental cost of fabrication tools.

2. Site Development

The costs in this category are derived from the MMA document *Estimated Site Development Costs of the MMA in Chile* by M. A. Gordon and dated February 1999. Dr. Gordon is the MMA Division Head for Site Development. Since frequent reference will be made to this document below we will refer to it as the *site development document*.

The personnel costs shown assigned to WBS 2 are those of the MMA construction engineer assigned to oversee the contract construction both at the Chajnantor site and at the OSF site near San Pedro de Atacama.

2.2 Maintain Mining Claims

Protection of the site from incursion by others wishing to conduct exploratory excavations is assured by the MMA Project (in this case through AUI) holding the exploratory mining rights to the site.

2.3 Contract A&E Studies

Architectural and Engineering studies for development of the civil works on the array site and the civil works for the Operations Support Facility. Cost of these professional fees is budgeted as follows: 5% of the construction cost is allocated for architectural fees (building design) and 2% of the construction cost is allowed for engineering design work (roads, utilities, cable trenching).

2.5.3 Contract Array Site Civil Works

The civil works needed to develop the array site are described in the Project Book Chapter 16 and in the site development document.

The costs are derived from the site development document as follows.

- Items 01.23 and 01.24 have been removed from the tasking. These items refer to oxygenation equipment and the technical approach taken in the estimate is not the one to be adopted for the MMA;
- Items 1.14 and 1.14.1 have been removed. The telephone system between the site and the OSF is included in the OSF/Array Link, WBS 2.7 below;
- Item 1.16 has been removed. This is the OSF/Array Link, costed in WBS 2.7;
- The number of antenna pads has been reduced from the 145 needed for an array of 40 antennas to 116, the number needed for the same multi-configurations of a 32 element array. This affects items 1.06, 1.07, 1.08 and 1.10 in the site development document;
- The site development document includes 12% contingency for all civil works. This contingency has been removed and replaced with 20% as the percentage contingency for all civil works including buildings, roads, cables, trenching, antenna foundations etc.

The costs include all electrical and fiber optic cables. The annual expense for the contract array site civil works is assumed to be 75% the first year and 25% the second year. An illustration of the MMA use of the site is shown on the following page.

It is assumed that the land for the array site, public (or *fiscal*) land is made available to the MMA by the Republic of Chile at no charge or on the basis of only a nominal rent.

2.6.3 Contract OSF Civil Works

The civil works needed to develop the Operations Support Facility near San Pedro de Atacama are described in the Project Book Chapter 16 and in the site development document.

The costs are derived from the site development document as follows.

- Item 2.17 has been removed. This is the cost of houses to be built in the OSF compound for use by senior MMA operations staff. The cost has been transferred to the operations budget;
- Items 2.02, 2.14, and 2.20 have been adjusted to the scope of a 32 element array with the cost difference noted as an adjustment in scope;
- The 12% contingency that is incorporated in the costs tabulated in the site development document has been removed. It has been replaced by 20% contingency.

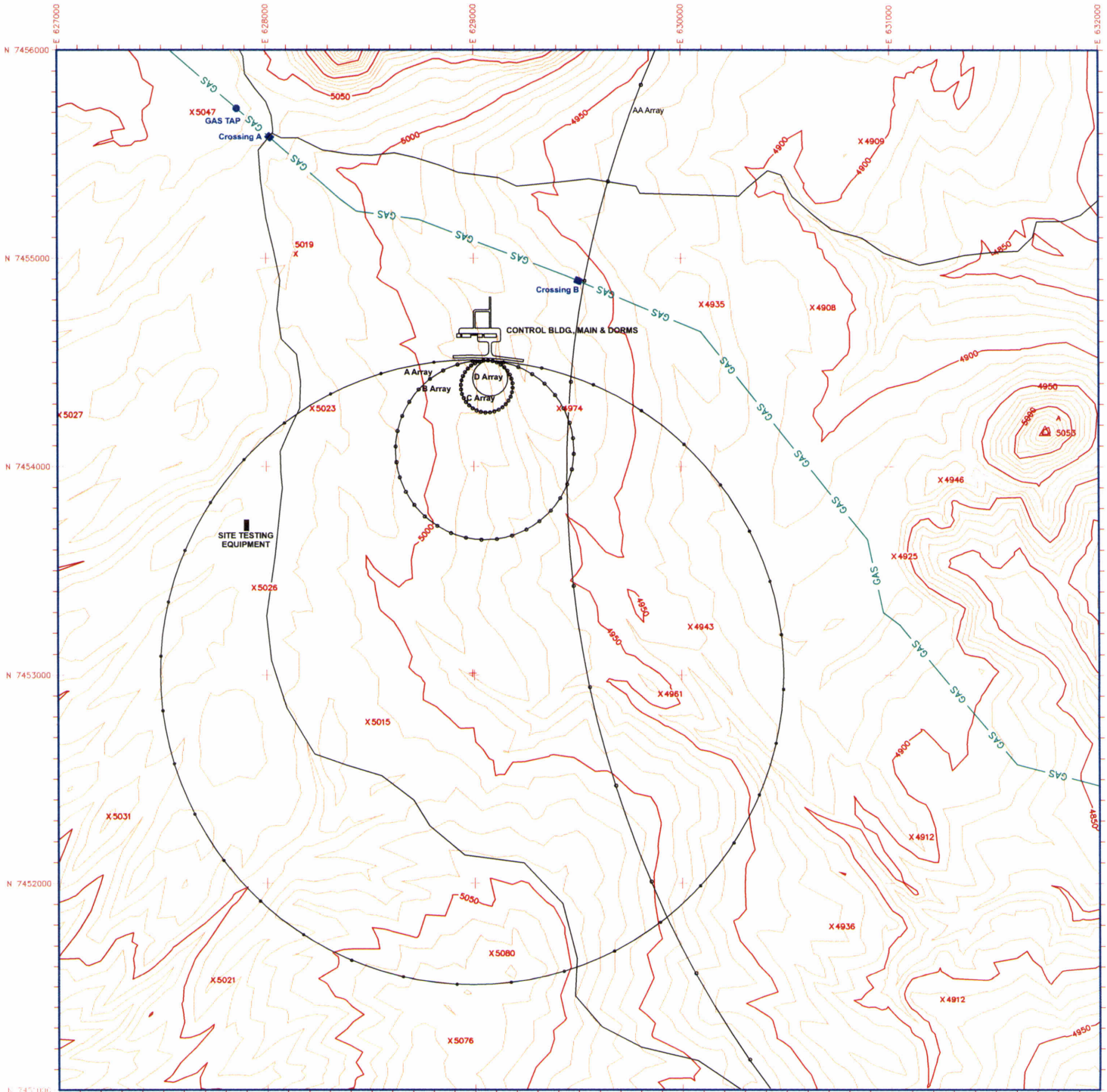


NATIONAL RADIO
ASTRONOMY OBSERVATORY

TOPOGRAPHIC MAP
OF
LLANO DE CHAJNANTOR, CHILE



CONTOUR INTERVAL: 10m
TOPOGRAPHIC INFORMATION WAS TAKEN FROM
AERIAL PHOTOGRAPHY (1981-1982) BY INSTITUTO
GEOGRAFICO MILITAR DE CHILE, HAVING A SCALE
OF 1:45000. UTM COORDINATES ARE TAKEN FROM
IC SA56 MAP PUBLISHED IN 1985



- A Array Ø3000 m 36 Elements
- B Array Ø 860 m 36 Elements
- C Array Ø 250 m 36 Elements
- D Array Ø 85 m 36 Elements
- AA Array Ø 10,000 m >>36 Elements

Pipeline Crossing Points
 Crossing A N7455582.0 E628019.5
 Crossing B N7454892.4 E629505.2
 Crossing C N7449474.2 E637712.1
 GAS TAP N7455719.9 E627861.4

See crossing plan drawing & Science Preserve drawing

— GAS — GA New Pipeline Location Feb. 25, 1998



A Array Center N7453009.4 E628991.0

- The cost of the construction camp, including the cost of housing the workers, has been added to 2.6.3.

It is assumed that the land for the OSF is public (*fiscal*) land made available by the Republic of Chile to the MMA at no cost or the cost of only a nominal rent. The annual expense for the contract OSF civil work is assumed to be 75% the first year and 25% the second year.

2.7.3 OSF/Array Link Contract Civil Works

The OSF/Array link is a communications link between the array site in the Altiplano near Cerro Chajnantor at 16,500 feet elevation and the Operations Support Facility approximately 50 kilometers distant that is at approximately 8200 feet elevation. The MMA will be operated from the OSF. The OSF/Array link is an optical fiber communications link that carries both data and telephone transmission. The cost is derived from the site development document as follows:

- Items 1.16 and 1.14 are the link costs; these are added;
- The 12% contingency that is used in the site development document is removed and a contingency of 20% is accumulated for these costs.

2.8.1 Equip the Array Site

Equipment for the array site is tabulated in the site development document. The major piece of capital equipment is the electrical generation equipment. These are gas turbines, catalog items. The cost is derived from the site development document as follows:

- The 10% contingency has been removed from the cost of the generators;
- The cost of office, safety and shop equipment has been added to the cost of the generators and that cost is assigned to array construction because it is needed for that purpose;
- A contingency of 15% is assigned to the sum above;
- The cost of vehicles and test equipment, a sum of \$2200k is accumulated as a cost for the operating budget.

2.8.2 Equip Operations Support Facility

Equipment for the array site is tabulated in the site development document. It includes the cost of furnishings, electronic test equipment and shop equipment. Half the cost of the electronic test equipment is accumulated as a cost for the operating budget and the remaining sum is retained as the construction cost. A contingency of 15% is used.

3. Antenna

3.1 Antenna Engineering Support

Includes the cost of 4 antenna design engineers for the two years 2001-2002 while they are engaged in testing the prototype antennas and drafting the specifications and terms of the contract for the production run of antennas.

3.8.10 Sign Transporter Contract

This is the contract for the first of the three antenna transporters needed. This first transporter will be delivered to the VLA site so that it can be used in the evaluation of the transportability of the two prototype antennas. When the test interferometer is disassembled this first antenna transporter will be shipped to Chile (see 3.81.1 below).

3.7 Procurement of Antenna #2

Antenna #2 is obtained by exercising an option written in to the contract for the first prototype antenna. Antenna #2, like antenna #1, will be delivered to, and erected at, the VLA site. The two antennas will be connected interferometrically so that precise tests can be made of the performance of the prototype antennas. The cost figure given here is the average of the costs provided to the MMA Project as budgetary estimates by two experienced antenna vendors, assuming that the second antenna is in fact procured via an option in the contract for antenna #1. 30% contingency is used.

3.9 Sign Contract for Production Antennas

A payment to bind the contract for the production series of antennas.

3.11 Accept Antenna #3 at OSF

Antenna #3 is the first of the production series of antennas to be delivered. The contract will call for it to be delivered and erected at the OSF in Chile. The MMA Project will accept it there. The engineering time assigned to this acceptance task is the time of MMA Project antenna engineers evaluating and characterizing the delivered antenna.

The cost of antenna #3 and the entire production series of antennas is derived from the average of budgetary estimates provided to the MMA Project at our request by two experienced antenna vendors. These estimates included shipment to Chile and erection at the OSF. A contingency of 30% is used for the production series of antennas.

The antenna RFP will specify that the antenna be an altitude over azimuth design. A visual example of one such design that was done as part of the MMA Design and Development phase is presented on the following page. Details of this particular design are given in MMA Memo 240.

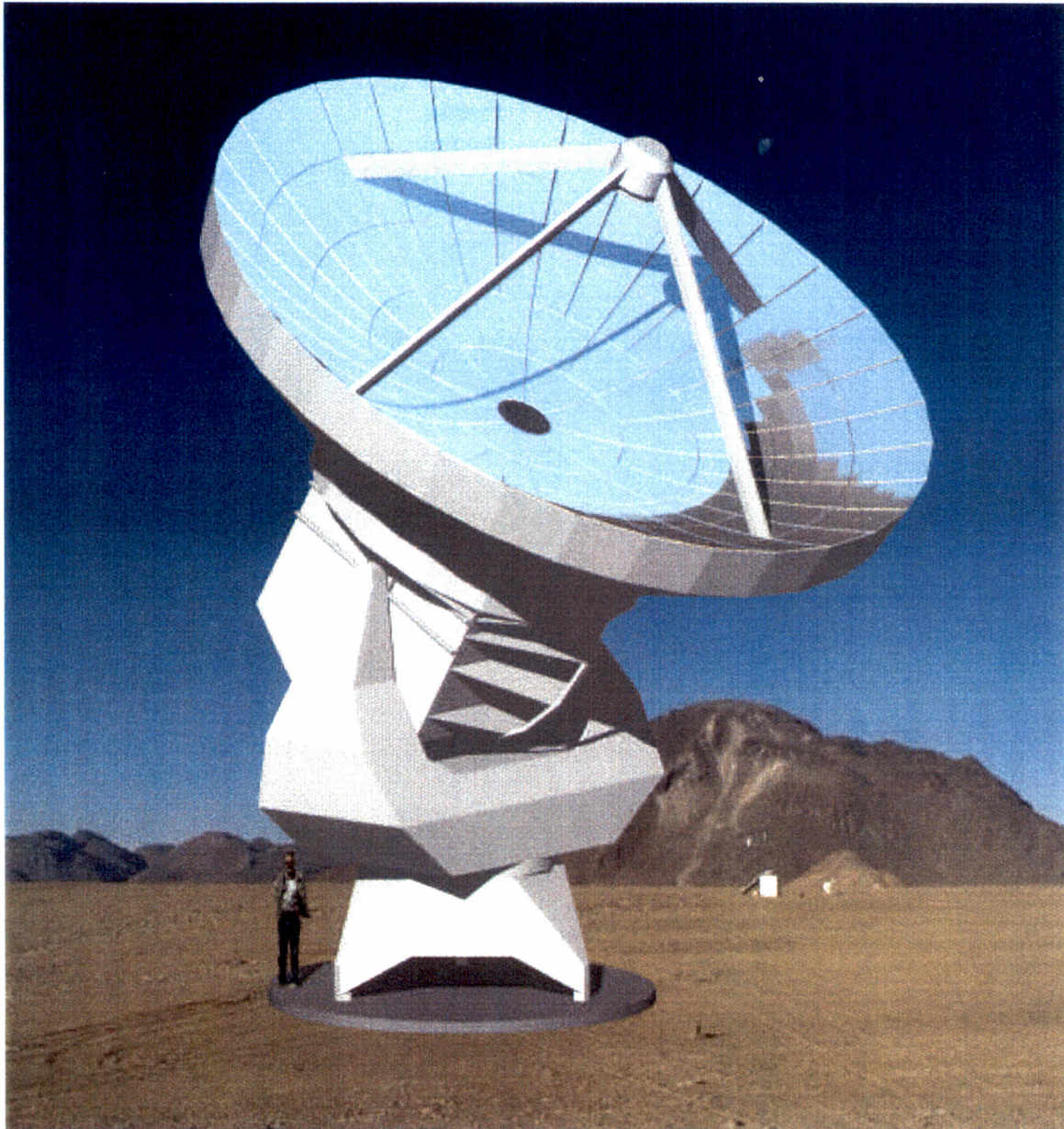
3.12.1 Outfit and Verify Antenna #3 at the OSF

This task includes the engineering and technician time needed to install on the antenna the hardware provided by the MMA Project. Such hardware includes the receiver package, all the IF, LO and scientific instrument control cabling, and cryogenic equipment.

3.12.2 Move, Install and Verify Antenna #3 on Site

Once the antenna is outfitted at the OSF it will be transported, fully assembled and fully functional, on the antenna transporter from the OSF to the Chajnantor array site. It will be placed on one of the antenna foundations on site. MMA Project technicians will confirm that the integrity of the antenna was preserved

A 10-m Antenna Design for the Millimeter Array



J. Lugten¹, J. Kingsley¹, J. Cheng¹, V. Gasho¹, and M. Fleming²

¹National Radio Astronomy Observatory

²Berkeley Illinois Maryland Association

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in the process of transporting it to the site. When that assessment is complete the antenna will be turned over to the array commissioning and operations staff.

3.13 - 3.70.2 Accept, Outfit and Verify Antennas #4 - 32

Repetition of the tasks 3.11, 3.12 for each of the antennas #4 through #32 that completes the array of 32 antennas on-site needed for the U.S. Reference Project. The delivery tasks for each antenna are noted separately here, and in the WBS Gantt chart, as a way of establishing the pace of the project in time. Note that antennas #1 and #2 that were part of the test interferometer at the VLA site are also delivered to the Chajnantor site in this same time period (see tasks 3.79-3.80).

3.71 - 3.78.2 Accept, Outfit and Verify Antennas #33-36

Repetition of the tasks 3.11, 3.12 for each of the antennas #33 through #36 that make up the augmentation to the scope of the U.S. Reference Project that was requested by the scientists comprising the Millimeter Array Advisory Committee. The costs for all tasks associated with the procurement, outfitting and verification of antennas #33-36 are accumulated as adjustments to the scope of the U.S. Reference Project.

3.79.1 Antenna #1 Reassembled at OSF

Includes the cost and effort involved in disassembling antenna #1, the initial prototype antenna, at the VLA site, shipping it to the OSF and reassembling it at the OSF.

3.79.2 Outfit and Verify Antenna #1 at the OSF

This task includes the engineering and technician time needed to install on the antenna the hardware provided by the MMA Project. Such hardware includes the receiver package, all the IF, LO and scientific instrument control cabling, and cryogenic equipment.

3.79.3 Move, Install and Verify Antenna #1 on Site

Once the antenna is outfitted at the OSF it will be transported, fully assembled and fully functional, on the antenna transporter from the OSF to the Chajnantor array site. It will be placed on one of the antenna foundations on site. MMA Project technicians will confirm that the integrity of the antenna was preserved in the process of transporting it to the site. When that assessment is complete the antenna will be turned over to the array commissioning and operations staff.

3.80.1 Antenna #2 Reassembled at OSF

Includes the cost and effort involved in disassembling antenna #2, the second prototype antenna, at the VLA site, shipping it to the OSF and reassembling it at the OSF.

3.80.2 Outfit and Verify Antenna #2 at the OSF

This task includes the engineering and technician time needed to install on the antenna the hardware provided by the MMA Project. Such hardware includes the receiver package, all the IF, LO and scientific instrument control cabling, and cryogenic equipment.

3.80.3 Move, Install and Verify Antenna #2 on Site

Once the antenna is outfitted at the OSF it will be transported, fully assembled and fully functional, on the antenna transporter from the OSF to the Chajnantor array site. It will be placed on one of the antenna foundations on site. MMA Project technicians will confirm that the integrity of the antenna was preserved in the process of transporting it to the site. When that assessment is complete the antenna will be turned over to the array commissioning and operations staff.

3.81.1 Contract for Transporter #1 Move to Site

Contract shipment of antenna transporter #1 from the test interferometer at the VLA site to the OSF.

3.81.2 Contract for Transporters #2, #3

Two more antenna transporters are procured under contract. One of these is needed for the MMA U.S. Reference Project, the other is needed to accommodate the additional antennas desired by the scientists on the Millimeter Array Advisory Committee. The third transporter is accounted for as a scope adjustment.

4. Receivers

4.1.1 Prototype Production Receiver Cryogenics

Final assembly of the cryogenic refrigeration system for the prototype of the MMA receiver package. Includes compressor, all cryogenic lines, and the cold stations mounted in the cryogenic dewar.

4.1.2 Prototype Production Receiver Package

Final assembly of the MMA prototype receiver. Includes prototypes of the receiver inserts for the 211-275 GHz frequency band together with the LO and IF hardware, and all control instrumentation. Also includes the entire cryogenic system, 4.1.1 above. This is a complete prototype receiver populated with only a subset of the final complement of receiver inserts.

4.1.6.1 Machine Dewars

The cryogenic dewar is a cylindrical stainless steel vessel approximately a meter in diameter and 1.5 meters in height. An example of such a dewar is shown in the photograph on the following page. It is machined from tubular stock and finished with welded flanges and bottom cover. The costs shown here are the costs experienced at the NRAO in fabricating similar dewars for the NRAO 12 Meter Telescope. The shop times and materials costs come directly from this experience. Adjustments are made to the scope to restore the cost to the requirements of the U.S. Reference Project.

4.1.6.2 Fabricate Cryogenic Subsystems

The MMA baseline cryogenic system consists of a commercial Gifford-McMahan 15 K refrigerator to which a Joule-Thompson expansion circuit is added to obtain a cold station at approximately 3.6 K. The Gifford-McMahan refrigerators needed for the MMA are in common use on more than 100 receivers presently operating at the NRAO. The Joule-Thompson (J-T) circuit is also in common use at the NRAO for all its



The receiver cryogenic dewar. The refrigerator can be seen mounted under the dewar.

millimeter-wavelength receivers. The J-T is built in-house. The costs quoted here are the costs realized in practice at the NRAO. An adjustment to scope is made. See Chapter 6 of the MMA Project Book.

4.1.6.3 Fabricate Windows, IR filters, etc

The optical components for the receiver package will be fabricated under contract to the NRAO designs. The windows are the windows and lenses through which the beam from the subreflector is passed to the receiver. The IR filters reflect heat away from the cryogenic refrigerator so as to minimize the load on the refrigerator. These components are derivatives of components used on the receivers of the NRAO 12 Meter Telescope.

4.1.8 Fabricate Receiver Package Instrumentation and Electronics

The receiver instrumentation is used to tune, electronically, the receiver frequency response to the needs of the scientist using the MMA and to tune the local oscillator appropriately for the same purpose. The instrumentation includes such functions as monitoring the level of the local oscillator and implementation of a servo loop to keep the gain in a pre-determined range. The level of the intermediate frequency is similarly monitored and controlled. Information is passed via the array monitor and control system. The MMA receiver instrumentation is a derivative of the instrumentation used on the NRAO 12 Meter Telescope receivers. For the MMA it will be built in-house aided by some board assembly done under contract. An adjustment to scope is made.

4.1.9 Fabricate Receiver Inserts

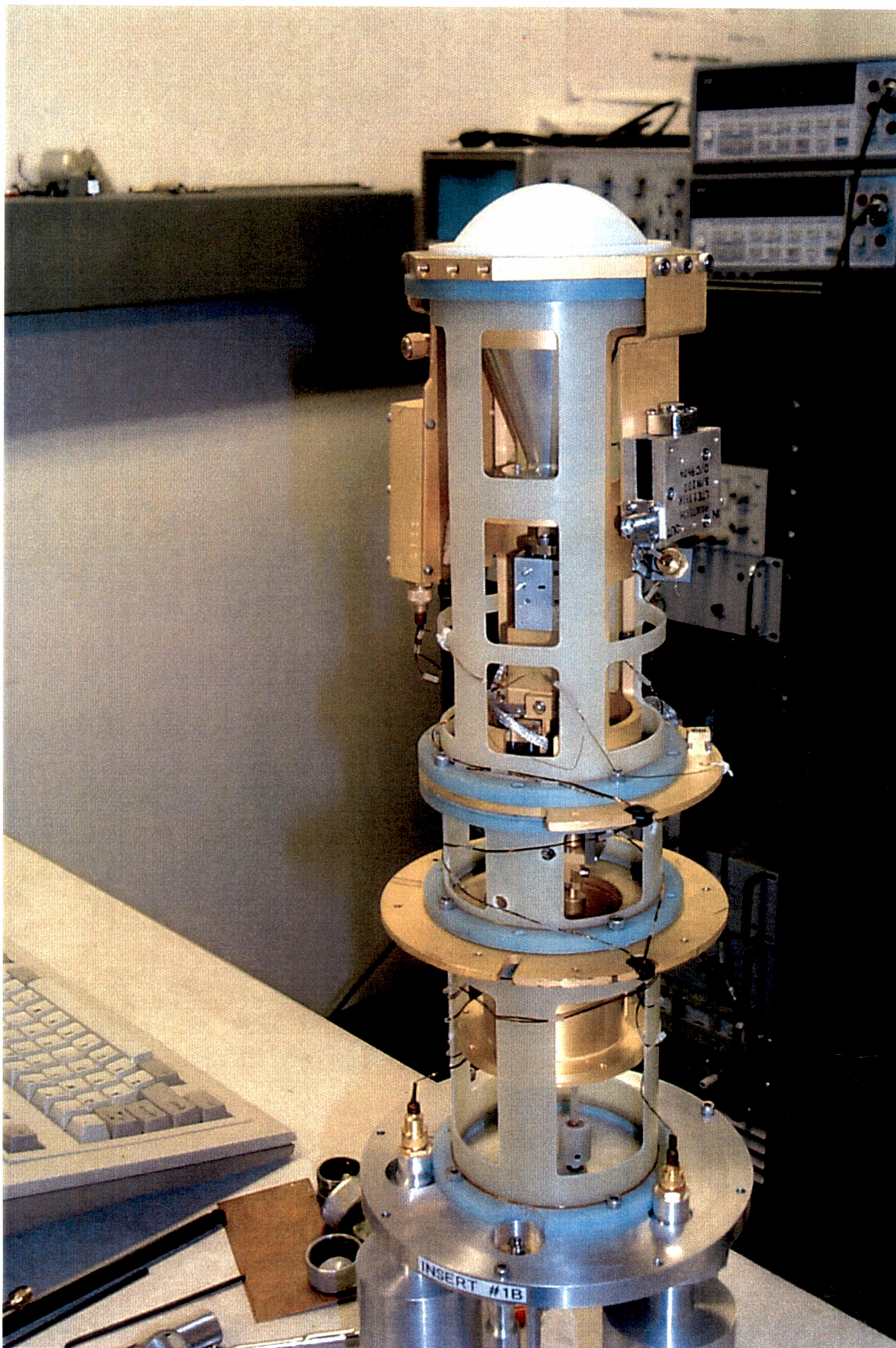
The receiver insert, or module, is the fundamental unit of the multi-frequency MMA receiver. Each MMA antenna has one 4 Kelvin cryogenic dewar into which receiver inserts are mounted. Each receiver insert consists of a lens, a feed horn, an orthomode transducer or optical device to split the polarizations, a SIS mixer covering a particular frequency range, a tunable source of local oscillator power, an intermediate frequency (IF) amplifier and control circuitry. This task involves assembly of all of these components, and testing of each completed receiver insert. Costs are derived from experience in doing the same tasks for the receivers on the NRAO 12 Meter Telescope. A photograph of a receiver insert is shown on the following page.

4.1.10 Assemble Receiver Package

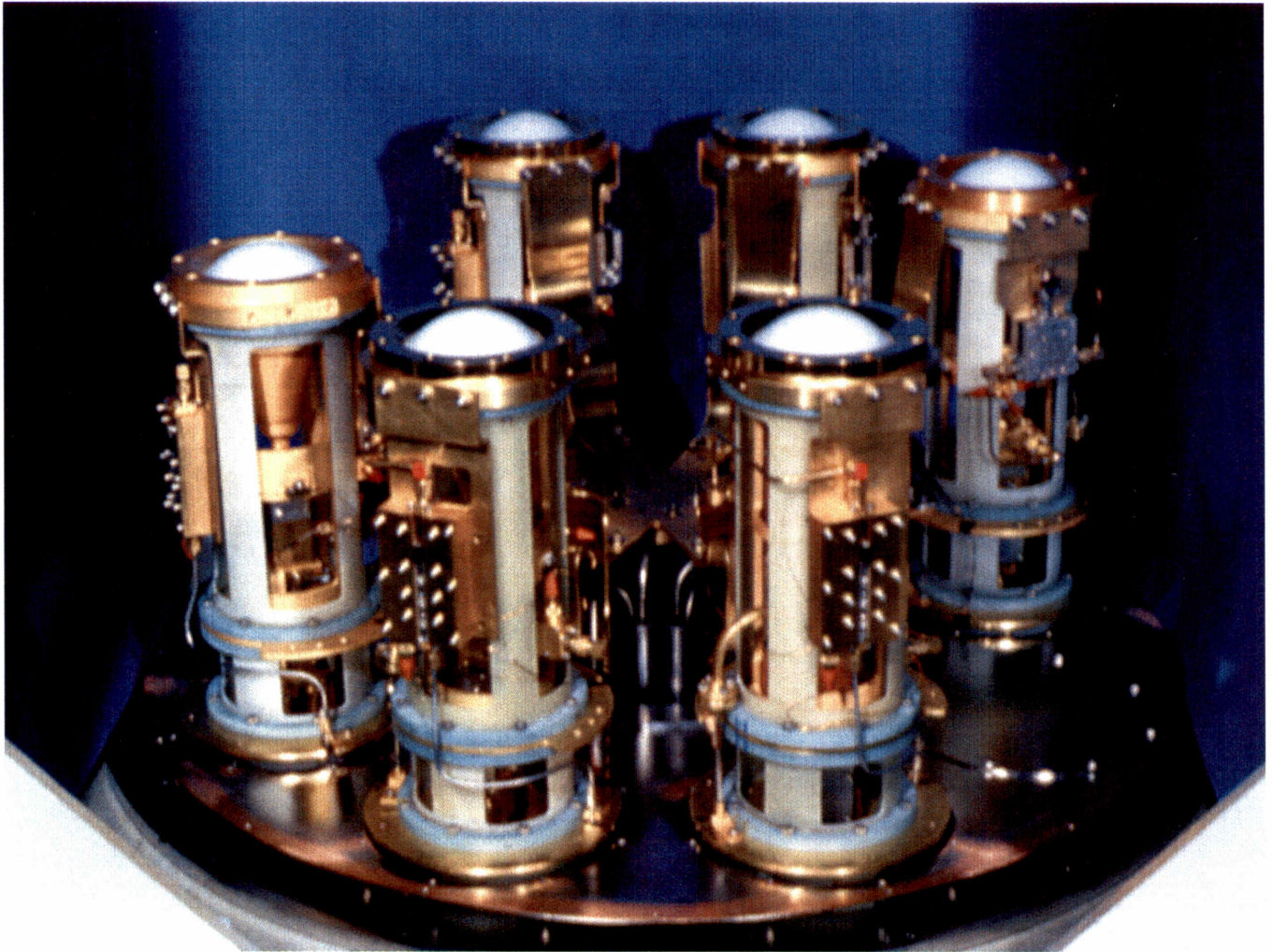
This task includes the time needed by the staff of engineers and technicians to incorporate the receiver inserts in the cryogenic dewar, to install the windows, filters and optical components and to test. A photograph of the deliverable of this task, six receiver modules mounted in the cryogenic dewar, is shown on the page after next (i.e., following the photograph of the receiver insert).

4.1.10.1 Integrate Receiver Instrumentation and Subassembly

This task mates the completed receiver package, the cryostat with the receiver inserts installed, with the instrumentation control package. Tests are made of the completed receiver assembly using computer communication via the monitor and control system. When complete the receiver is shipped to the OSF in Chile. Shipping costs are not included here, they appear in 1.1.2.



Example of a SIS Receiver module or insert.



Six receiver inserts shown mounted in the dewar.

4.2.1 211-275 GHz Module

The 211-275 SIS Receiver module is the first of the SIS mixers to be delivered. The module consists of a SIS mixer that is of the design described in Chapter 5 of the MMA Project Book. It is a balanced mixer, image-separating that is integrated with the IF amplifier. The SIS device is fabricated under contract. The mixer block is fabricated under contract. The SIS mixer is diced, mounted in the block and tested in-house. This task does not include the local oscillator. Costs are derived from experience in fabricating SIS mixers for receivers on the NRAO 12 Meter Telescope.

4.2.1.2 Design and Verify Optics

Includes the design of the feedhorn and lens. Verification of the amplitude and phase frequency response is done using a prototype in an anechoic chamber. Task does not include fabrication of production components (this is done in 4.2.1.4.1).

4.2.1.3 Design Module

Includes the design of the mixer block and physical layout of the module. Task does not include fabrication of production components (this is done in 4.2.1.4.1).

4.2.1.4 Contract Fabrication

Fabrication by contract with out of house vendors to machine the SIS mixer blocks, the OMT, feedhorn, waveguide and lenses. Materials costs are minimal, expense is machine shop time. Costs are based on experience with components fabricated for receivers on the NRAO 12 Meter Telescope.

4.2.1.5 Install SIS Mixer and Test Modules

In house assembly of the SIS mixer module. Involves dc testing of the SIS wafer delivered from the fabricator, dicing of the areas of the wafer determined to have SIS devices meeting the dc test requirements, mounting of those devices in the mixer block and testing the performance in a cryogenic fixture.

4.2.2 602-720 GHz Module

The module consists of a SIS mixer that is of the design described in Chapter 5 of the MMA Project Book. It is a balanced mixer, image-separating that is integrated with the IF amplifier. The SIS device is fabricated under contract. The mixer block is fabricated under contract. The SIS mixer is diced, mounted in the block and tested in-house. This task does not include the local oscillator. Costs are derived from experience in fabricating SIS mixers for receivers on the NRAO 12 Meter Telescope. This task is an adjustment to the scope of the U.S. Reference Project; the costs are accumulated accordingly.

4.2.2.2 Design and Verify Optics

Includes the design of the feedhorn and lens. Verification of the amplitude and phase frequency response is done using a prototype in an anechoic chamber. Task does not include fabrication of production components (this is done in 4.2.1.4.1). This task is an adjustment to the scope of the U.S. Reference Project; the costs are accumulated accordingly.

4.2.2.3 Design Module

Includes the design of the mixer block and physical layout of the module. Task does not include fabrication of production components (this is done in 4.2.1.4.1). This task is an adjustment to the scope of the U.S. Reference Project; the costs are accumulated accordingly.

4.2.2.4 Contract Fabrication

Includes the design of the mixer block and physical layout of the module. Task does not include fabrication of production components (this is done in 4.2.1.4.1). This task is an adjustment to the scope of the U.S. Reference Project; the costs are accumulated accordingly.

4.2.2.5 Install SIS Mixer and Test Modules

In house assembly of the SIS mixer module. Involves dc testing of the SIS wafer delivered from the fabricator, dicing of the areas of the wafer determined to have SIS devices meeting the dc test requirements, mounting of those devices in the mixer block and testing the performance in a cryogenic fixture. This task is an adjustment to the scope of the U.S. Reference Project; the costs are accumulated accordingly.

4.2.3 275-370 GHz Receiver Module

The module consists of a SIS mixer that is of the design described in Chapter 5 of the MMA Project Book. It is a balanced mixer, image-separating that is integrated with the IF amplifier. The SIS device is fabricated under contract. The mixer block is fabricated under contract. The SIS mixer is diced, mounted in the block and tested in-house. This task does not include the local oscillator. Costs are derived from experience in fabricating SIS mixers for receivers on the NRAO 12 Meter Telescope.

4.2.3.2 Design and Verify Optics

Includes the design of the feedhorn and lens. Verification of the amplitude and phase frequency response is done using a prototype in an anechoic chamber. Task does not include fabrication of production components (this is done in 4.2.1.4.1).

4.2.3.3 Design Module

Includes the design of the mixer block and physical layout of the module. Task does not include fabrication of production components (this is done in 4.2.1.4.1).

4.2.3.4 Contract Fabrication

Includes the design of the mixer block and physical layout of the module. Task does not include fabrication of production components (this is done in 4.2.1.4.1).

4.2.3.5 Install SIS Mixer and Test Modules

In house assembly of the SIS mixer module. Involves dc testing of the SIS wafer delivered from the fabricator, dicing of the areas of the wafer determined to have SIS devices meeting the dc test requirements, mounting of those devices in the mixer block and testing the performance in a cryogenic fixture

4.2.4 91 - 119 GHz Receiver Module

The module consists of a SIS mixer that is of the design described in Chapter 5 of the MMA Project Book. It is a balanced mixer, image-separating that is integrated with the IF amplifier. The SIS device is fabricated under contract. The mixer block is fabricated under contract. The SIS mixer is diced, mounted in the block and tested in-house. This task does not include the local oscillator. Costs are derived from experience in fabricating SIS mixers for receivers on the NRAO 12 Meter Telescope.

4.2.4.2 Design and Verify Optics

Includes the design of the feedhorn and lens. Verification of the amplitude and phase frequency response is done using a prototype in an anechoic chamber. Task does not include fabrication of production components (this is done in 4.2.1.4.1).

4.2.4.3 Design Module

Includes the design of the mixer block and physical layout of the module. Task does not include fabrication of production components (this is done in 4.2.1.4.1).

4.2.4.4 Contract Fabrication

Includes the design of the mixer block and physical layout of the module. Task does not include fabrication of production components (this is done in 4.2.1.4.1).

4.2.4.5 Install SIS Mixer and Test Modules

In house assembly of the SIS mixer module. Involves dc testing of the SIS wafer delivered from the fabricator, dicing of the areas of the wafer determined to have SIS devices meeting the dc test requirements, mounting of those devices in the mixer block and testing the performance in a cryogenic fixture

4.2.5 163 - 211 GHz Receiver Module

The module consists of a SIS mixer that is of the design described in Chapter 5 of the MMA Project Book. It is a balanced mixer, image-separating that is integrated with the IF amplifier. The SIS device is fabricated under contract. The mixer block is fabricated under contract. The SIS mixer is diced, mounted in the block and tested in-house. This task does not include the local oscillator. Costs are derived from experience in fabricating SIS mixers for receivers on the NRAO 12 Meter Telescope.

4.2.5.2 Design and Verify Optics

Includes the design of the feedhorn and lens. Verification of the amplitude and phase frequency response is done using a prototype in an anechoic chamber. Task does not include fabrication of production components (this is done in 4.2.1.4.1).

4.2.5.3 Design Module

Includes the design of the mixer block and physical layout of the module. Task does not include fabrication of production components (this is done in 4.2.1.4.1).

4.2.5.4 Contract Fabrication

Includes the design of the mixer block and physical layout of the module. Task does not include fabrication of production components (this is done in 4.2.1.4.1).

4.2.5.5 Install SIS Mixer and Test

In house assembly of the SIS mixer module. Involves dc testing of the SIS wafer delivered from the fabricator, dicing of the areas of the wafer determined to have SIS devices meeting the dc test requirements, mounting of those devices in the mixer block and testing the performance in a cryogenic fixture

4.2.6 385 - 500 GHz Receiver Module

The module consists of a SIS mixer that is of the design described in Chapter 5 of the MMA Project Book. It is a balanced mixer, image-separating that is integrated with the IF amplifier. The SIS device is fabricated under contract. The mixer block is fabricated under contract. The SIS mixer is diced, mounted in the block and tested in-house. This task does not include the local oscillator. Costs are derived from experience in fabricating SIS mixers for receivers on the NRAO 12 Meter Telescope. This task is an adjustment to the U.S. Reference Project; the costs are accumulated accordingly.

4.2.6.2 Design and Verify Optics

Includes the design of the feedhorn and lens. Verification of the amplitude and phase frequency response is done using a prototype in an anechoic chamber. Task does not include fabrication of production components (this is done in 4.2.1.4.1). This task is an adjustment to the U.S. Reference Project; the costs are accumulated accordingly.

4.2.6.3 Design Module

Includes the design of the mixer block and physical layout of the module. Task does not include fabrication of production components (this is done in 4.2.1.4.1). This task is an adjustment to the U.S. Reference Project; the costs are accumulated accordingly.

4.2.6.4 Contract Fabrication

Includes the design of the mixer block and physical layout of the module. Task does not include fabrication of production components (this is done in 4.2.1.4.1). This task is an adjustment to the U.S. Reference Project; the costs are accumulated accordingly.

4.2.6.5 Install SIS Mixer and Test

In house assembly of the SIS mixer module. Involves dc testing of the SIS wafer delivered from the fabricator, dicing of the areas of the wafer determined to have SIS devices meeting the dc test requirements, mounting of those devices in the mixer block and testing the performance in a cryogenic fixture. This task is an adjustment to the U.S. Reference Project; the costs are accumulated accordingly.

4.2.7 125 - 163 GHz Receiver Module

The module consists of a SIS mixer that is of the design described in Chapter 5 of the MMA Project Book. It is a balanced mixer, image-separating that is integrated with the IF amplifier. The SIS device is fabricated under contract. The mixer block is fabricated under contract. The SIS mixer is diced, mounted in the block and tested in-house. This task does not include the local oscillator. Costs are derived from experience in fabricating SIS mixers for receivers on the NRAO 12 Meter Telescope.

4.2.7.2 Design and Verify Optics

Includes the design of the feedhorn and lens. Verification of the amplitude and phase frequency response is done using a prototype in an anechoic chamber. Task does not include fabrication of production components (this is done in 4.2.1.4.1).

4.2.7.3 Design Module

Includes the design of the mixer block and physical layout of the module. Task does not include fabrication of production components (this is done in 4.2.1.4.1).

4.2.7.4 Contract Fabrication

Includes the design of the mixer block and physical layout of the module. Task does not include fabrication of production components (this is done in 4.2.1.4.1).

4.2.7.5 Install SIS Mixer and Test

In house assembly of the SIS mixer module. Involves dc testing of the SIS wafer delivered from the fabricator, dicing of the areas of the wafer determined to have SIS devices meeting the dc test requirements, mounting of those devices in the mixer block and testing the performance in a cryogenic fixture

4.3 HFET Receiver Modules

Design and fabrication of the HFET amplifier modules for the two longest wavelength MMA frequency bands are directly adapted from identical work recently completed at the NRAO for the NASA Microwave Anisotropy Probe (MAP) spacecraft. The MMA amplifiers at 33-50 GHz and 67-95 GHz cover nearly the same frequency ranges as did similar amplifiers designed and built for MAP; the MMA will require only subtle variations on those designs. The number of HFET amplifiers needed for the MMA U.S. Reference Project is fewer than the number built for MAP. The costs noted here are scaled from the MAP experience. The major cost item is for contract fabrication of a InP wafer; such a wafer will have many thousands of HFETs. See Chapter 5 of the MMA Project Book.

5. Local Oscillator System

5.1 LO Reference: Prototype Systems

Refinement and completion of the prototype LO reference distribution system developed in the MMA Design and Development Project.

5.2 LO Reference: Production System

This task includes the workforce needed to assemble and test the local oscillator reference system. The LO reference system is described in Chapter 9 of the MMA Project Book; one can see how it fits within the overall MMA system by reviewing Chapter 8 of the Project Book.

5.1.2 Hydrogen Maser Frequency Standard and Rubidium Standard

The frequency reference for the MMA is derived from a hydrogen maser. A less precise Rubidium frequency standard is used as a backup and for error-checking the hydrogen standard. These are commercial instruments, widely used at the NRAO and other observatories.

5.1.3 8 GHz Phase Lock Oscillator and Distributor

Commercial oscillator. Used for the IF de-multiplexing.

5.1.4 10 GHz Phase Lock Oscillator and Distributor

Commercial oscillator. Used for the IF de multiplexing.

5.1.5 12 GHz Phase Lock Oscillator and Distributor

Commercial oscillator. Used for the IF de multiplexing.

5.1.6 14 GHz Phase Lock Oscillator and Distributor

Commercial oscillator. Used for the IF de multiplexing.

5.1.7 3.2 - 5.2 GHz Synthesizer

Commercial synthesizer. Used for baseband conversion.

5.1.8 3.2 - 5.2 GHz Phase Lock Loop and Fringe Generator

Commercial synthesizer and fringe rotation synthesizer. Phase lock loop built in-house.

5.1.9 Sampler Clock, 4 GHz Phase Lock Oscillator and Distributor

Commercial oscillator. Used as the time standard for the digital samplers and for the 125 MHz de-multiplexor. (See Figure 4 of Chapter 8 of the MMA Project Book).

5.1.10 LO Reference Generator

Provides the first LO for the SIS receivers and the second LO for the HFET receivers. Generates a comb of reference frequencies at each antenna from which the needed tone is selected via the monitor and control system.

5.1.11 LO Reference Distributor–Control Building

From the hydrogen maser frequency standard, it generates the fundamental LO frequencies to be distributed to each antenna. Built in-house, adapted from the design used in the VLA.

5.1.12 Microwave Round-Trip Phase Measurement

Instrumentation to return part of the LO reference from each antenna to the control building where the phase of the returned signal is compared with the phase of the transmitted LO reference so that a correction can be implemented to preserve the LO reference phase at the antenna. Assembled in-house from commercial components.

5.1.13 10-15 GHz Frequency Synthesizer

Commercial synthesizer tunable in the frequency intervals needed for the LO drivers.

5.1.14 First LO Fringe Generator

Accepts as input the phase switch frequency spectrum and the fringe rotation frequency from the monitor and control system. The output is used as control of the f2 synthesizer and the correlator. In-house design and assembly.

5.1.15 16 GHz Phase Lock Oscillator

Commercial hardware. Used as a second LO when the IF output from the receiver is in the mode with two 4-8 GHz outputs; the 16 GHz oscillator is mixed with one channel of the receiver output to convert it to 8-12 GHz for transmission on the fiber.

5.1.16 26 GHz Phase Lock Oscillator

Commercial hardware. Used as a second LO for the HFET receivers.

5.1.17 LO Reference Distributor–Antenna

Instrument to distribute the reference LO frequencies at the antenna to the receivers, the fringe rotation switch and the second Los. In-house design and assembly.

5.1.18 VXCO Clean-up Loop

The variable crystal oscillator is commercial hardware. Assembly in-house will build this oscillator into a module to accept input from the LO Reference distributor (5.1.17) and produce output needed by the chosen LO driver.

5.1.19 Power Supply Module

Commercial power supply assembled into a custom module.

5.1.20 Bins/Racks (assemble and test)

Assembly of the LO modules into standard racks and bins. There will be one rack at each antenna and approximately four racks of LO reference hardware in the central control building. The racks and bins are commercial equipment; assembly of modules into the racks is done in-house.

5.3 Millimeter LO Drivers

Engineering effort to finalize design.

5.3.1 Design and System Integration

Engineering design to integrate fully the LO drivers with the system of multiplier-driven receiver local oscillators.

5.3.2 72-95 GHz Source

Engineering and technician labor required to assemble the frequency source from a fundamental YIG-tuned oscillator followed by a pair of amplifiers and multipliers. The components are obtained commercially. The mount and tuning circuitry are fabricated in-house. Assembly and test is done by the MMA engineering and technician staff.

5.3.3 100-120 GHz Source

Engineering and technician labor required to assemble the frequency source from a fundamental YIG-tuned oscillator followed by a pair of amplifiers and multipliers. The components are obtained commercially. The mount and tuning circuitry are fabricated in-house. Assembly and test is done by the MMA engineering and technician staff.

5.3.4 87 - 108 GHz Source

Engineering and technician labor required to assemble the frequency source from a fundamental YIG-tuned oscillator followed by a pair of amplifiers and multipliers. The components are obtained commercially. The mount and tuning circuitry are fabricated in-house. Assembly and test is done by the MMA engineering and technician staff.

5.3.5 65 - 85 GHz Source

Engineering and technician labor required to assemble the frequency source from a fundamental YIG-tuned oscillator followed by a pair of amplifiers and multipliers. The components are obtained commercially. The mount and tuning circuitry are fabricated in-house. Assembly and test is done by the MMA engineering and technician staff.

5.4 Millimeter Local Oscillator Multiplier Chains

Engineering efforts to finalize designs.

5.4.1 Design and System Integration

Engineering effort to integrate fully the chain of multipliers with the source driver and the requirements of the receiver package.

5.4.2 211 - 275 GHz Receiver LO

Engineering and technician labor required to do the following tasks:

- Supervise the contract diode fabrication;
- Supervise the contract machining of the diode mount;
- Fabricate the bias and control circuitry for the diode;
- Assemble the completed multiplier and perform verification tests;
- Integrate the multiplier in a test fixture using the source driver and controlled by the MMA monitor and control hardware; verify performance.

5.4.3 602 - 720 GHz Receiver LO

Engineering and technician labor required to do the following tasks:

- Supervise the contract diode fabrication;
- Supervise the contract machining of the diode mount;
- Fabricate the bias and control circuitry for the diode;
- Assemble the completed multiplier and perform verification tests;
- Integrate the multiplier in a test fixture using the source driver and controlled by the MMA monitor and control hardware; verify performance.

The 602 - 720 GHz receiver is an adjustment to the scope of the U.S. Reference Project. The entire cost of producing this LO is accumulated as a scope adjustment.

5.4.4 275 - 370 GHz Receiver LO

Engineering and technician labor required to do the following tasks:

- Supervise the contract diode fabrication;
- Supervise the contract machining of the diode mount;
- Fabricate the bias and control circuitry for the diode;
- Assemble the completed multiplier and perform verification tests;
- Integrate the multiplier in a test fixture using the source driver and controlled by the MMA monitor and control hardware; verify performance.

5.4.5 163 - 211 GHz Receiver LO

Engineering and technician labor required to do the following tasks:

- Supervise the contract diode fabrication;
- Supervise the contract machining of the diode mount;
- Fabricate the bias and control circuitry for the diode;

- Assemble the completed multiplier and perform verification tests;
- Integrate the multiplier in a test fixture using the source driver and controlled by the MMA monitor and control hardware; verify performance.

5.4.6 385 - 500 GHz Receiver LO

Engineering and technician labor required to do the following tasks:

- Supervise the contract diode fabrication;
- Supervise the contract machining of the diode mount;
- Fabricate the bias and control circuitry for the diode;
- Assemble the completed multiplier and perform verification tests;
- Integrate the multiplier in a test fixture using the source driver and controlled by the MMA monitor and control hardware; verify performance.

This receiver is beyond the scope of the U.S. Reference Project. These costs are accumulated as a scope adjustment.

5.4.7 125 - 163 GHz Receiver LO

Engineering and technician labor required to do the following tasks:

- Supervise the contract diode fabrication;
- Supervise the contract machining of the diode mount;
- Fabricate the bias and control circuitry for the diode;
- Assemble the completed multiplier and perform verification tests;
- Integrate the multiplier in a test fixture using the source driver and controlled by the MMA monitor and control hardware; verify performance.

5.4.8 33 - 45 GHz Receiver LO

The local oscillator for the low frequency receivers based on HFET amplifiers is derived directly from the source drivers. This task involves the fabrication of coupling structures to those sources and of source driver selection hardware. In-house effort.

6. IF System

Engineering and technician labor to procure commercial hardware, integrate the antenna-based components into the complete array IF system. This task is detailed in Chapters 8 and 9 of the MMA Project Book.

6.2 Production Test and Laboratory Equipment

Electronic test equipment and fabrication test fixtures for assembly of the production MMA IF instrumentation.

6.3 IF Multiplexer

The IF multiplexer consists of commercial switches, power dividers, power combiners, filters, amplifiers, gain and phase equalizers and a frequency up-converter. There are two IF multiplexers at each antenna. They multiplex the IF input from the receivers onto the optical fiber for transmission to the central control building. Assembly and test and integration of these components with the MMA monitor and control system is done in-house.

6.4 IF Demultiplexer

In the control building there is one rack per antenna in which the two IF signals are demultiplexed and prepared for input to the correlator. The demultiplexer hardware consists of commercial power splitters, filters, amplifiers, gain and phase equalizers and frequency down-converters. Assembly and test, and integration of these components with the MMA monitor and control system is done in-house.

6.5 IF Matrix Switch

The IF Matrix switch follows the IF demultiplexer in the signal path in the control building. In a flexible way under computer control it connects the IF input to the baseband converters. The matrix switch is made up of commercial components assembled, tested and integrated with the MMA monitor and control system in-house.

6.6 Baseband Converter

Each 8 GHz wide IF from the matrix switch is followed by 4 2 GHz wide analog baseband converters (BBC). The BBC will be fabricated under contract to MMA specifications. Test and integration with the MMA monitor and control system will be done in-house.

6.7 Power Supply Module

Commercial power supplies built in-house into modules for the IF rack at each antenna.

6.8 Bins/Racks (Assemble and Test)

All the IF hardware modules are assembled in standard MMA rack bins and installed in the MMA standard racks. The bins and racks are commercial products or will be built to MMA specifications in contract machine shops. The integrated modules will be assembled into the racks and tested by MMA staff.

7. Optical Fiber System

Engineering and technician labor to procure commercial hardware, integrate the antenna-based components into the complete array optical fiber data transmission system. This task is detailed in Chapters 8 and 9 of the MMA Project Book.

7.1 Production Test and Laboratory Equipment

Electronic test equipment and fabrication test fixtures for assembly of the production MMA optical fiber implementation.

7.2 Intermediate Frequency Transmitters and Receivers

Transmitters, one per antenna, to put 16 GHz of analog IF data on the single mode optical fiber at 1550 nm and receivers, one per antenna located at the array control building, to receive that IF transmission. The transmitters and receivers are commercial products procured under competitive bid. They are assembled into standard MMA modules, integrated with the array monitor and control system, and tested by MMA staff.

7.3 LO Reference Transmitters and Receivers

Receivers, one per antenna, to receive on the single mode optical fiber at 1550 nm the LO reference signal transmitted from the central control building. The transmitters and receivers are commercial products procured under competitive bid. They are assembled into standard MMA modules, integrated with the array monitor and control system, and tested by MMA staff.

7.4 Microwave Round-trip Phase Transmitters and Receivers

A pair of transmitters and receivers, one pair per antenna, to receive and return the narrow band microwave reference used to compensate for instrumental phase variations. A corresponding pair of transmitters and receivers is fabricated for location at the array control building. The transmitters and receivers are commercial products procured under competitive bid. They are assembled into standard MMA modules, integrated with the array monitor and control system, and tested by MMA staff.

7.5 Monitor and Control Transmitters and Receivers

Transmitters, one per antenna, for communication on the monitor and control system via the single mode optical fiber at 1550 nm and receivers, one per antenna located at the array control building, to receive that transmission. The transmitters and receivers are commercial products procured under competitive bid. They are assembled into standard MMA modules, integrated and tested by MMA staff.

7.6 Power Supply Module

Commercial power supplies built in-house into modules for the optical fiber data transmission rack at each antenna.

7.7 Bins/Racks (Assemble and Test)

All the optical fiber hardware modules are assembled in standard MMA rack bins and installed in the MMA standard racks. The bins and racks are commercial products or will be built to MMA specifications in contract machine shops. The integrated modules will be assembled into the racks and tested by MMA staff.

8. Correlator

The MMA correlator is built in-house by the engineering group that built the VLA correlator, the VLBA correlator and the GBT correlator. It is described in Chapter 10 of the MMA Project Book. The correlator chip represents a factor of two increase in the level of integration compared to the GBT chip but is otherwise of the same generation of technology. The MMA correlator chip will be fabricated commercially under contract. The correlator boards (integrated assemblies of chips) will be assembled under contract. The finished boards will be assembled in quadrants of the correlator by the MMA correlator engineering and

technical staff. The completed correlator quadrants will be tested and integrated with the MMA monitor and control system in-house. The finished correlator will require approximately 22 standard equipment racks and it will require approximately 100 kW of electrical power continuously.

A photograph of the correlator similar to that built for the MMA test interferometer is shown on the next page. The rack on the left contains the sampler hardware; the one on the right contains the correlation hardware. The MMA correlator itself will be very much larger, and enormously more capable, than the test correlator shown in this photograph.

8.1 Digital Sampler, 4 GHz

Each IF from each antenna has a bandwidth of 8 GHz. This bandwidth is sub-divided into four bands of 2 GHz and each sub-band is digitally sampled prior to correlation. The sampler must therefore run at 4 GHz. The needed sampler will either be designed and built in-house as a cascade of commercially-available lower speed samplers or, if a 4 GHz sampler is available, it will be purchased. In either case the integration of the sampler with the correlator hardware and with the IF transmission system will be done in-house.

8.2 Digital FIR Filter

The digital finite response filter (FIR) will be used to sample, digitally, the IF passband in those observing modes where a bandwidth of less than 2 GHz per IF subband is required. The FIR is of a design done by the MMA staff as part of the Design and Development Phase of the Project; it consists of a parallel grouping of field programmable gate arrays (FPGA). The FPGA will be obtained commercially. Assembly, test and integration of the FIR filter will be done in-house. See Chapter 8 of the MMA Project Book or MMA Memo 204.

9. Computing

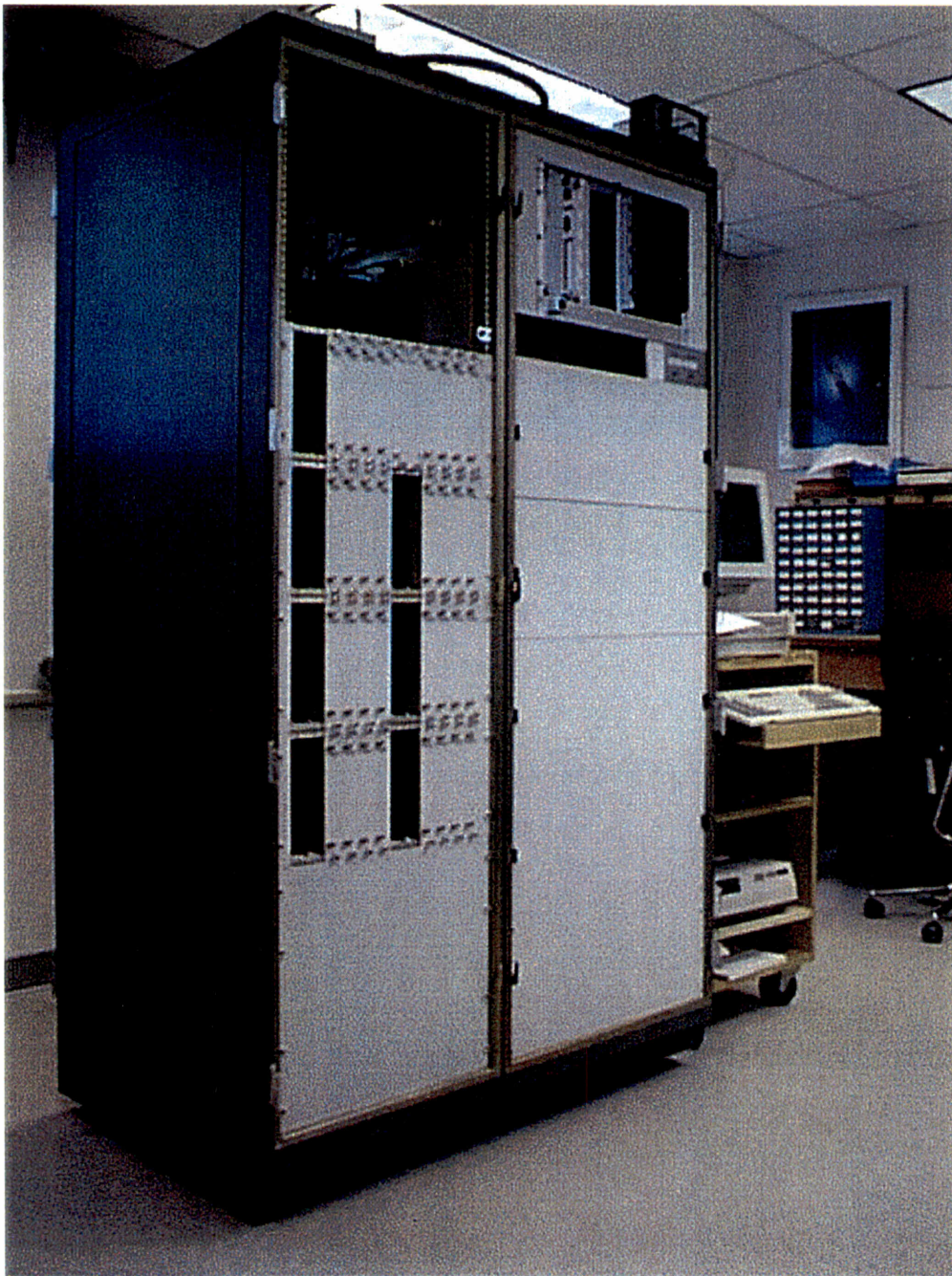
Costs assigned to this task at the highest level are the costs associated with providing the computing hardware needed for operation of the MMA and for development of the software system. It does not include computing hardware (e.g. workstations) for the MMA staff who are not assigned duties as part of the MMA computing task. The task is described in Chapters 12 and 13 of the MMA Project Book.

9.1.1 Test Interferometer Control and Analysis

The primary purpose of the test interferometer is to evaluate the performance of the prototype antennas so that contracting for the production suite of MMA antennas can be done with confidence that they will meet their performance specifications. This task includes the software needed for this testing purpose and will be assembled from existing interferometer packages and/or from commercial software.

9.1.2 MMA Correlator Software

Software to control the correlator functioning, written in-house in collaboration with the MMA correlator engineering staff. Correlator control is done via the MMA monitor and control system. Task includes testing the M/C interface.



Correlator for the test interferometer.

9.1.3 Multi-Antenna and Sub-array Control

Software task to subdivide the array into smaller groupings of antennas that have the capability to observe simultaneously but independent of one another. Single dish capability—the capability to use each individual antenna independently of the others as a total power telescope—is a limiting subset of this task.

9.1.4 Operators and Observers Interfaces

Display screens and capabilities needed either by the scientists using the array or by the array operations staff.

9.1.5 Deliver Control Software

Software needed to control the array. First done as a rudimentary system to commission the first antennas in Chile and to permit basic scientific observations. Software evolves in sophistication guided by the experiences of the scientists who participate in MMA commissioning.

9.1.6 Maintenance

Control and interface software maintenance. Personnel cost is a critical part of array operations.

9.2.1 Static Scheduling System

Software system to schedule scientific programs on the MMA in fixed, pre-determined blocks of time.

9.2.2 Dynamic Scheduling Simulations

Simulations using a representative set of model scientific observations each of which has requirements for environmental conditions necessary for its successful completion. Using the actual site environmental data (e.g., wind, atmospheric opacity) a simulated scheduling program will be written that permits each observation to be run at the time when site conditions would have been acceptable for it. The goal is to refine the intellectual basis for a true dynamical scheduling program and to determine the fractional scientific gain of such a system beyond that that would have been achieved had the array been scheduled solely on a static system.

9.2.3 Dynamic Scheduling Prototype

Software effort required to incorporate the understanding gained in 9.2.2 into a prototype of a dynamic scheduling prototype software system.

9.2.4 Dynamic Scheduling Implementation

Implementation of the prototype dynamic scheduling system on the interim MMA. Includes development of the prototype to a full system implementation.

9.3.1 Prototype Proposal Preparation Software

Prototype software to receive and format the observing requests of scientists proposing to use the MMA. This task aids the MMA data flow system that translates the astronomer's scientific goals as he/she proposes them into instructions for array control and transfers that information to the operating system of the array including setup of the correlator all without the information being manually entered by the MMA staff.

9.3.2 Production Version

Software effort needed to implement the production version of the proposal preparation software described in 9.3.1.

9.4.1 Automated Calibration and Imaging Heuristics

Software effort needed to specify the process by which data taken by the MMA can be calibrated in real-time such that images of the observation in progress can be communicated to the scientist-observer and such as to provide the scientist with images as a fundamental data product of the MMA.

9.4.2 Prototype Image Pipeline

Specification of the hardware and software process by which automated calibration and real-time imaging can be achieved.

9.4.3 Parallelization Studies and Implementation

Effort assigned to the task of identifying those algorithms that are part of the real-time calibration and imaging process that can be parallelized; implementation of parallelization algorithms for this purpose.

9.4.4 Initial Image Pipeline Operations

This task is the initial realization of tasks 9.4.1, 9.4.2, and 9.4.3. It includes parallel software to produce calibrated images in real-time of some fraction of the interim MMA scientific programs.

9.4.5 Production Image Pipeline

This task includes the effort required to refine the experience gained through implementation of 9.4.4 into a production system of calibration and real-time imaging that is consistent with the needs and experience of scientists using the MMA.

9.5.1 Prototype Distributed Archive

Software effort required to define fully the software needed for the MMA data archive consistent with the output of 9.2, 9.3 and 9.4 above.

9.5.2 Evaluate Storage Hardware

Effort required to assess the capabilities of options for archival storage hardware that satisfies the MMA requirements. Task includes a recommendation of the approach for the MMA.

9.5.3 Production Archive

Software and hardware realization of the MMA data archive.

9.6.1 Define MMA Data Formats

Software effort needed to review the data communication needs of the MMA and to recommend a data format that will facilitate that transfer.

9.6.2 MMA Filler and Format Conversions

Software effort needed to choose the data format most appropriate for use on-line in the MMA and to convert, if necessary, that format to any other format needed by the scientist or elsewhere in the MMA system.

9.6.3 MMA-Specific Calibrations

Software effort required to review the product of the MMA with the assumptions made by the MMA imaging analysis software AIPS++ as to acceptable input. Where these two are incompatible it may be necessary to establish specific calibrations to bring the two software environments into agreement.

9.6.5 Maintenance

On-going maintenance of the MMA imaging pipeline and archival software. Costs assigned to the interim operations budget of the MMA.

10. System Integration

At the highest level this task includes the cost of the office and laboratory facilities needed for the test interferometer to be built at the VLA site.

10.4 Test Interferometer Site Preparation

Effort and materials needed to trench and cable the site for the test interferometer.

10.10.4 Prototype Antenna Outfitting

Engineering and Technician effort required to equip the initial prototype antenna with all MMA-provided equipment. This includes the antenna evaluation receiver, cables, and computer communications.

10.10.4.3 Evaluation Receiver #1/Antenna #1 Integration

Effort and materials necessary for construction of the receiver needed to evaluate the first prototype antenna. This receiver will be capable of holographic observations at 86 GHz and of observations to assess the gain of the antenna at a frequency as high as 230 GHz.

Installation
interferometer

10.10.5 Integration Holography System/Antenna

Effort required to equip the initial prototype antenna with hardware needed to make holographic observations.

10.10.6 Integration Metrology/Antenna

Effort required to equip the antenna with instruments needed to measure distances and angles on the antenna so as to evaluate its ability to meet the performance specifications.

10.10.7 Antenna #1 Integration and Testing

Effort and materials allocated to the purpose of the antenna evaluation. Does not include the time of scientists involved in making the pointing tests, gain tests and so forth; these costs are included in 11.4 below.

10.10.9 Antenna #2 Outfitting

Effort and materials needed to equip prototype antenna #2 with MMA-supplied instrumentation.

10.11 Test Interferometer

Programming, engineering and technician effort needed to perform the antenna evaluations using the test interferometer (i.e., prototype antennas #1 and #2). Tests to be accomplished with the test interferometer are outlined in the MMA Project Book, Chapter 11.

10.11.1 Antenna Evaluation and Characterization

Technician effort to assist with the antenna evaluations and perform tests as required.

10.11.3 Revise Interface Specifications

Engineering effort. On the basis of experience with the prototype antennas revisions will be made to the interface specifications. The revisions will be used for the production quantity hardware.

10.11.5 Operations Personnel Training

Hiring and training of the initial MMA-Chile technical staff. Initial training will be done at the VLA site on the MMA test interferometer. These staff members will be transferred permanently to Chile as soon as facilities are in place on the array site and at the OSF. Costs are allocated to the operations budget.

10.11.5.1 Recruit Initial Chile Operations Staff

Hiring and training of the initial complement of array operators for Chile. These people will be trained on the test interferometer. Costs are allocated to operations, not construction.

10.12 Disassemble Test Interferometer

Effort to remove the two prototype antennas and all other permanent MMA facilities from the VLA site and prepare them for shipment to the OSF in Chile. Does not include the cost of shipping.

10.13 On-Site System Integration

Engineering and technician effort needed in Chile to accept MMA hardware from the U.S. as it arrives and integrate it into the MMA system in Chile as that system grows. These people become the operating staff of the MMA. Their cost is allocated to the operating budget, not the construction budget.

11. Calibration and Imaging

Scientific aid in placing contracts for the phase calibration radiometers and the amplitude calibration system.

11.1 Radiometric Phase Design and Prototype

Contract with a university group to design and prototype a 183 GHz radiometer capable of meeting the MMA specifications to measure the column of atmospheric water vapor above the antenna. Oversight provided by MMA engineering staff.

11.2 Production Fabrication of Phase Monitor Radiometer

Contract for the fabrication of the 183 GHz phase monitor radiometer. One such system will be built for each antenna. The phase monitors will be integrated with the MMA receiver package and will communicate via the MMA monitor and control system. Fabrication done under contract; integration done by the MMA staff.

11.2.5 Verification on-Site

Effort by U.S.-based MMA technician to train Chile site techs on the installation and proper use of the phase monitor radiometer.

11.3 Production Fabrication of Dual-Load Amplitude Calibration System

The MMA dual-Load amplitude calibration system was designed in the Design and Development phase by the MDC participating university groups. It will be fabricated under contract; integration of the system will be done by the MMA staff. See Chapter 3 of the MMA Project Book.

11.4 Imaging Studies and Project Support

Scientific support to the project. Tasks for this group include taking and analyzing holographic data for the two prototype antennas on the test interferometer; taking and analyzing all engineering data on the test interferometer for the purpose of debugging hardware designs and improving the presentation and utility of the operator's and astronomer's software interface. As the project moves to Chile this group does also and becomes responsible for commissioning each new feature of the MMA. Costs for this group transfer to the operating budget in 2002.

11.5 Imaging and Algorithm Development

Imaging studies done in support of project decisions. Scientist/programmers involved will provide the Project management with an assessment of the ramifications to the imaging performance of the array each proposed change to the baseline technical description of the instrument may make.

APPENDIX A

WORK BREAKDOWN STRUCTURE



MMA Construction Tasks

All Tasks selected

WBS	Task	Start	Finish	Duration	2001				2002				2003				2004				2005				2006				2007			
					Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1	Administration	2001-01-01	2008-01-01	365.6w																												
1.1	Project Management	2001-01-01	2007-12-27	365w																												
1.1.1	Management, Planning, and Oversight	2001-01-01	2007-12-27	365w																												
1.1.2	Business Operations	2001-01-01	2007-12-27	365w																												
1.1.3	Chilean Operations	2001-01-01	2007-12-27	365w																												
1.1.4	Safety and Health	2001-01-01	2007-12-27	365w																												
1.1.5	Personnel	2001-01-01	2007-12-27	365w																												
1.1.6	Project Science Office	2001-01-01	2007-12-27	365w																												
1.1.7	AUI Management	2001-01-01	2007-12-27	365w																												
1.2	Engineering	2001-01-01	2008-01-01	365.6w																												
1.2.1	System Engineering--Phase II	2001-01-01	2008-01-01	1828d																												
1.2.2	Documentation System	2001-01-01	2008-01-01	1828d																												
1.2.3	Production Engineering	2001-01-01	2008-01-01	1828d																												
1.3	US Facilities	2001-01-01	2007-12-27	365w																												
1.3.1	CDL Permanent Facilities	2001-01-01	2005-12-29	261w																												
1.3.2	Manufacturing Facilities	2001-01-01	2007-12-27	365w																												
1.3.3	Common Infrastructure	2001-01-01	2007-12-27	365w																												
2	Site Development	2001-01-01	2008-01-01	365.6w																												
2.1	Review Legalities Regarding Array and OSF Sites	2001-01-01	2001-07-02	131d																												
2.2	Maintain Mining claims	2001-01-04	2008-01-01	365w																												
2.3	Contract A&E Studies	2001-01-01	2001-10-31	218d																												
2.4	Hire Construction Manager for Chile	2001-03-01	2001-03-01	0d																												
2.5	Array Site	2001-06-01	2004-03-12	145.2w																												
2.5.1	Prepare Site Development Bid Packages	2001-06-01	2001-12-03	26.4w																												
2.5.1.1	Prepare Package for Array Site	2001-06-01	2001-11-01	110d																												
2.5.1.2	Review Bid Packages	2001-11-02	2001-12-03	22d																												
2.5.1.3	Bid Civil Works Construction	2001-12-03	2001-12-03	0d																												
2.5.2	Evaluate Array Site Bid Response	2002-02-01	2002-02-28	4w																												
2.5.2.1	Review Bids	2002-02-01	2002-02-21	15d																												
2.5.2.2	Recommend Contractors	2002-02-21	2002-02-28	6d																												

Milestones: **bold type**
Summary Tasks: underline

Task Milestone Summary



MMA Construction Tasks

All Tasks selected

WBS	Task	Start	Finish	Duration	2001				2002				2003				2004				2005				2006				2007			
					Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
2.5.2.3	Award Array Site Contracts	2002-02-28	2002-02-28	0d					▲																							
<u>2.5.3</u>	<u>Contract Array Site Civil Works</u>	<u>2002-03-01</u>	<u>2004-03-12</u>	<u>106.2w</u>					■	■	■	■	■	■	■	■																
2.5.3.1	Array Site	2002-03-01	2004-02-27	521d					■	■	■	■	■	■	■	■																
2.5.3.2	Inspect Completed Site Constr	2004-03-01	2004-03-12	2w													■	■	■	■												
2.5.3.3	Accept Site Facility	2004-03-12	2004-03-12	0d													▲															
<u>2.6</u>	<u>Operations Support Facility</u>	<u>2001-06-01</u>	<u>2004-03-15</u>	<u>145.4w</u>	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■												
<u>2.6.1</u>	<u>Prepare OSF Bid Packages</u>	<u>2001-06-01</u>	<u>2001-12-03</u>	<u>26.4w</u>	■	■	■	■	■	■	■	■																				
2.6.1.1	Prepare Package for OSF	2001-06-01	2001-11-01	110d	■	■	■	■	■	■	■	■																				
2.6.1.2	Review Bid Packages	2001-11-02	2001-12-03	22d					■	■	■	■																				
2.6.1.3	Bid Civil Works Construction	2001-12-03	2001-12-03	0d					▲																							
<u>2.6.2</u>	<u>Evaluate OSF Bid Response</u>	<u>2002-02-01</u>	<u>2002-03-01</u>	<u>4.2w</u>					■	■	■	■																				
2.6.2.1	Review Bids	2002-02-01	2002-02-21	15d					■	■	■	■																				
2.6.2.2	Recommend Contractors	2002-02-22	2002-03-01	6d					■	■	■	■																				
2.6.2.3	Award Contracts	2002-03-01	2002-03-01	0d					▲																							
<u>2.6.3</u>	<u>Contract OSF Civil Works</u>	<u>2002-03-04</u>	<u>2004-03-15</u>	<u>106.2w</u>					■	■	■	■	■	■	■	■	■	■	■	■												
2.6.3.1	Operations Support Facility	2002-03-04	2004-03-01	521d					■	■	■	■	■	■	■	■	■	■	■	■												
2.6.3.2	Inspect Completed OSF Constr	2004-03-02	2004-03-15	2w													■	■	■	■												
2.6.3.3	Accept OSF Facility	2004-03-15	2004-03-15	0d													▲															
<u>2.7</u>	<u>OSF/Array Link</u>	<u>2001-06-01</u>	<u>2002-12-13</u>	<u>80.2w</u>	■	■	■	■	■	■	■	■	■	■	■	■																
<u>2.7.1</u>	<u>Prepare OSF/Array Link Bid Package</u>	<u>2001-06-01</u>	<u>2001-12-03</u>	<u>26.4w</u>	■	■	■	■	■	■	■	■																				
2.7.1.1	Prepare Package for OSF/Array F/O Link	2001-06-01	2001-11-01	110d	■	■	■	■	■	■	■	■																				
2.7.1.2	Review Bid Package	2001-11-02	2001-12-03	22d					■	■	■	■																				
2.7.1.3	Bid OSF/Array Link Construction	2001-12-03	2001-12-03	0d					▲																							
<u>2.7.2</u>	<u>Evaluate Bid Response</u>	<u>2002-02-01</u>	<u>2002-03-01</u>	<u>4.2w</u>					■	■	■	■																				
2.7.2.1	Review Bids	2002-02-01	2002-02-21	15d					■	■	■	■																				
2.7.2.2	Recommend Contractors	2002-02-22	2002-03-01	6d					■	■	■	■																				
2.7.2.3	Award Contracts	2002-03-01	2002-03-01	0d					▲																							
<u>2.7.3</u>	<u>Contract Civil Works</u>	<u>2002-08-01</u>	<u>2002-12-13</u>	<u>19.4w</u>									■	■	■	■																
2.7.3.1	OSF/Array Link	2002-08-01	2002-11-29	87d									■	■	■	■																
2.7.3.2	Inspect Completed OSF/Array Link Constr	2002-12-02	2002-12-13	2w													■	■	■	■												

Milestones: **bold type**
Summary Tasks: underline

Task ■ Milestone ▲

Summary ■



MMA Construction Tasks

All Tasks selected

WBS	Task	Start	Finish	Duration	2001			2002			2003			2004			2005			2006			2007																																																	
					Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4																																												
2.7.3.3	Accept OSF/Array Link	2002-12-13	2002-12-13	0d																																																																				
<u>2.8</u>	<u>Prepare for Instrument Assembly</u>	<u>2003-09-01</u>	<u>2004-08-31</u>	52.4w																																																																				
2.8.1	Equip Array Site	2003-09-01	2004-08-31	262d																																																																				
2.8.2	Equip Operations Support Facility	2003-09-01	2004-08-31	262d																																																																				
3	Antenna	2001-01-01	2008-01-01	365.6w																																																																				
3.1	Antenna Engineering Support	2001-01-01	2007-12-27	365w																																																																				
3.3.40	Acceptance Tests Antenna #1	2001-04-09	2001-06-01	40d																																																																				
3.3.45	Delivery of Antenna #1	2001-06-01	2001-06-01	0d																																																																				
3.8.10	Sign Transporter Contract	2001-01-26	2001-01-26	0d																																																																				
3.8.15	Transporter Acceptance tests	2001-04-30	2001-06-01	5w																																																																				
3.8.20	Deliver/Accept Transporter #1	2001-06-01	2001-06-01	0d																																																																				
<u>3.7</u>	<u>Procurement of Antenna #2</u>	<u>2001-01-01</u>	<u>2001-12-28</u>	<u>52w</u>																																																																				
3.7.1	Antenna #2 Contract Supervision	2001-01-01	2001-12-28	52w																																																																				
3.7.2	Antenna #2 Acceptance tests	2001-11-05	2001-12-28	8w																																																																				
3.8	Negotiate Production Antenna Contract	2002-09-02	2002-12-31	87d																																																																				
3.9	Sign Contract for Production Antennas	2002-12-31	2002-12-31	0d																																																																				
3.10	Antenna Contract Supervision	2002-12-31	2007-12-28	261w																																																																				
3.11	Accept Antenna #3 at OSF	2004-04-02	2004-04-02	0d																																																																				
<u>3.12</u>	<u>Prepare Antenna #3</u>	<u>2004-04-05</u>	<u>2004-09-17</u>	<u>24w</u>																																																																				
3.12.1	Outfit & Verify Ant #3 at OSF	2004-04-05	2004-06-25	12w																																																																				
3.12.2	Move, Install & Verify Ant #3 on Site	2004-06-28	2004-09-17	12w																																																																				
3.13	Accept Antenna #4 at OSF	2004-08-01	2004-08-01	0d																																																																				
<u>3.14</u>	<u>Prepare Antenna #4</u>	<u>2004-08-02</u>	<u>2004-10-08</u>	<u>10w</u>																																																																				
3.14.1	Outfit & Verify Ant #4 at OSF	2004-08-02	2004-09-24	8w																																																																				
3.14.2	Move, Install & Verify Ant #4 on Site	2004-09-27	2004-10-08	2w																																																																				
3.15	Accept Antenna#5 at OSF	2004-10-01	2004-10-01	0d																																																																				
<u>3.16</u>	<u>Prepare Antenna #5</u>	<u>2004-10-01</u>	<u>2004-12-09</u>	<u>10w</u>																																																																				
3.16.1	Outfit & Verify Ant #5 at OSF	2004-10-01	2004-11-25	8w																																																																				
3.16.2	Move, Install & Verify Ant #5 on Site	2004-11-26	2004-12-09	2w																																																																				
3.17	Accept Antenna#6 at OSF	2004-12-01	2004-12-01	0d																																																																				

Milestones: **bold type**
Summary Tasks: underline

Task

Milestone

Summary



MMA Construction Tasks

All Tasks selected

WBS	Task	Start	Finish	Duration	2001				2002				2003				2004				2005				2006				2007			
					Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
<u>3.18</u>	<u>Prepare Antenna #6</u>	<u>2004-12-01</u>	<u>2005-02-07</u>	<u>10w</u>																												
3.18.1	Outfit & Verify Ant #6 at OSF	2004-12-01	2005-01-24	8w																												
3.18.2	Move, Install & Verify Ant #6 on Site	2005-01-25	2005-02-07	2w																												
3.19	Accept Antenna #7 at OSF	2005-01-17	2005-01-17	0d																												
<u>3.20</u>	<u>Prepare Antenna #7</u>	<u>2005-01-17</u>	<u>2005-03-25</u>	<u>10w</u>																												
3.20.1	Outfit & Verify Ant #7 at OSF	2005-01-17	2005-03-11	8w																												
3.20.2	Move, Install & Verify Ant #7 on Site	2005-03-14	2005-03-25	2w																												
3.21	Accept Antenna #8 at OSF	2005-03-01	2005-03-01	0d																												
<u>3.22</u>	<u>Prepare Antenna #8</u>	<u>2005-03-01</u>	<u>2005-05-09</u>	<u>10w</u>																												
3.22.1	Outfit & Verify Ant #8 at OSF	2005-03-01	2005-04-25	8w																												
3.22.2	Move, Install & Verify Ant #8 on Site	2005-04-26	2005-05-09	2w																												
3.23	Accept Antenna #9 at OSF	2005-04-04	2005-04-04	0d																												
<u>3.24</u>	<u>Prepare Antenna #9</u>	<u>2005-04-04</u>	<u>2005-06-10</u>	<u>10w</u>																												
3.24.1	Outfit & Verify Ant #9 at OSF	2005-04-04	2005-05-27	8w																												
3.24.2	Move, Install & Verify Ant #9 on Site	2005-05-30	2005-06-10	2w																												
3.25	Accept Antenna #10 at OSF	2005-05-09	2005-05-09	0d																												
<u>3.26</u>	<u>Prepare Antenna #10</u>	<u>2005-05-09</u>	<u>2005-07-15</u>	<u>10w</u>																												
3.26.1	Outfit & Verify Ant #10 at OSF	2005-05-09	2005-07-01	8w																												
3.26.2	Move, Install and Verify Ant #10 on Site	2005-07-04	2005-07-15	2w																												
3.27	Accept Antenna #11 at OSF	2005-06-20	2005-06-20	0d																												
<u>3.28</u>	<u>Prepare Antenna #11</u>	<u>2005-06-20</u>	<u>2005-08-26</u>	<u>10w</u>																												
3.28.1	Outfit & Verify Ant #11 at OSF	2005-06-20	2005-08-12	8w																												
3.28.2	Move, Install & Verify Ant #11 on Site	2005-08-15	2005-08-26	2w																												
3.29	Accept Antenna #12 at OSF	2005-07-25	2005-07-25	0d																												
<u>3.30</u>	<u>Prepare Antenna #12</u>	<u>2005-07-26</u>	<u>2005-10-03</u>	<u>10w</u>																												
3.30.1	Outfit & Verify Ant #12 at OSF	2005-07-26	2005-09-19	8w																												
3.30.2	Move, Install & Verify Ant #12 on Site	2005-09-20	2005-10-03	2w																												
3.31	Accept Antenna #13 at OSF	2005-09-05	2005-09-05	0d																												
<u>3.32</u>	<u>Prepare Antenna #13</u>	<u>2005-09-05</u>	<u>2005-11-11</u>	<u>10w</u>																												
3.32.1	Outfit & Verify Ant #13 at OSF	2005-09-05	2005-10-28	8w																												

Milestones: **bold type**
Summary Tasks: underline

Task Milestone

Summary



MMA Construction Tasks

All Tasks selected

WBS	Task	Start	Finish	Duration	2001				2002				2003				2004				2005				2006				2007						
					Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4			
3.32.2	Move, Install & Verify Ant #13 on Site	2005-10-31	2005-11-11	2w																															
3.33	Accept Antenna #14 at OSF	2005-10-10	2005-10-10	0d																		▲													
<u>3.34</u>	<u>Prepare Antenna #14</u>	<u>2005-10-10</u>	<u>2005-12-16</u>	<u>10w</u>																		■													
3.34.1	Outfit & Verify Ant #14 at OSF	2005-10-10	2005-12-02	8w																		■													
3.34.2	Move, Install & Verify Ant #14 on Site	2005-12-05	2005-12-16	2w																		■													
3.35	Accept Antenna #15 at OSF	2005-11-21	2005-11-21	0d																			▲												
<u>3.36</u>	<u>Prepare Antenna #15</u>	<u>2005-11-21</u>	<u>2006-01-27</u>	<u>10w</u>																		■													
3.36.1	Outfit & Verify Ant #15 at OSF	2005-11-21	2006-01-13	8w																		■													
3.36.2	Move, Install & Verify Ant #15 on Site	2006-01-16	2006-01-27	2w																		■													
3.37	Accept Antenna #16 at OSF	2006-01-16	2006-01-16	0d																			▲												
<u>3.38</u>	<u>Prepare Antenna #16</u>	<u>2006-01-16</u>	<u>2006-03-24</u>	<u>10w</u>																		■													
3.38.1	Outfit & Verify Ant #16 at OSF	2006-01-16	2006-03-10	8w																		■													
3.38.2	Move, Install & Verify Ant #16 on Site	2006-03-13	2006-03-24	2w																		■													
3.39	Accept Antenna #17 at OSF	2006-02-20	2006-02-20	0d																			▲												
<u>3.40</u>	<u>Prepare Antenna #17</u>	<u>2006-02-21</u>	<u>2006-05-01</u>	<u>10w</u>																		■													
3.40.1	Outfit & Verify Ant #17 at OSF	2006-02-21	2006-04-17	8w																		■													
3.40.2	Move, Install & Verify Ant #17 on Site	2006-04-18	2006-05-01	2w																		■													
3.41	Accept Antenna #18 at OSF	2006-03-15	2006-03-15	0d																			▲												
<u>3.42</u>	<u>Prepare Antenna #18</u>	<u>2006-03-16</u>	<u>2006-05-24</u>	<u>10w</u>																		■													
3.42.1	Outfit & Verify Ant #18 at OSF	2006-03-16	2006-05-10	8w																		■													
3.42.2	Move, Install & Verify Ant #18 on Site	2006-05-11	2006-05-24	2w																		■													
3.43	Accept Antenna #19 at OSF	2006-04-17	2006-04-17	0d																			▲												
<u>3.44</u>	<u>Prepare Antenna #19</u>	<u>2006-04-17</u>	<u>2006-06-23</u>	<u>10w</u>																		■													
3.44.1	Outfit & Verify Ant #19 at OSF	2006-04-17	2006-06-09	8w																		■													
3.44.2	Move, Install & Verify Ant #19 on Site	2006-06-12	2006-06-23	2w																		■													
3.45	Accept Antenna #20 at OSF	2006-05-15	2006-05-15	0d																			▲												
<u>3.46</u>	<u>Prepare Antenna #20</u>	<u>2006-05-16</u>	<u>2006-07-24</u>	<u>10w</u>																		■													
3.46.1	Outfit & Verify Ant #20 at OSF	2006-05-16	2006-07-10	8w																		■													
3.46.2	Move, Install & Verify Ant #20 on Site	2006-07-11	2006-07-24	2w																		■													
3.47	Accept Antenna #21 at OSF	2006-06-15	2006-06-15	0d																			▲												

Milestones: **bold type**
Summary Tasks: underline

Task █	Milestone ▲	Summary █
------------------------------------------------------------------	----------------------------------------------	-----------------------------------------------------------------------



MMA Construction Tasks
All Tasks selected

WBS	Task	Start	Finish	Duration	2001				2002				2003				2004				2005				2006				2007					
					Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4		
<u>3.48</u>	<u>Prepare Antenna #21</u>	<u>2006-06-16</u>	<u>2006-08-24</u>	<u>10w</u>																														
3.48.1	Outfit & Verify Ant #21 at OSF	2006-06-16	2006-08-10	8w																														
3.48.2	Move, Install & Verify Ant #21 on Site	2006-08-11	2006-08-24	2w																														
3.49	Accept Antenna #22 at OSF	2006-07-17	2006-07-17	0d																													2006-07-17	
<u>3.50</u>	<u>Prepare Antenna #22</u>	<u>2006-07-17</u>	<u>2006-09-22</u>	<u>10w</u>																														
3.50.1	Outfit & Verify Ant #22 at OSF	2006-07-17	2006-09-08	8w																														
3.50.2	Move, Install & Verify Ant #22 on Site	2006-09-11	2006-09-22	2w																														
3.51	Accept Antenna #23 at OSF	2006-08-15	2006-08-15	0d																													2006-08-15	
<u>3.52</u>	<u>Prepare Antenna #23</u>	<u>2006-08-16</u>	<u>2006-10-24</u>	<u>10w</u>																														
3.52.1	Outfit & Verify Ant #23 at OSF	2006-08-16	2006-10-10	8w																														
3.52.2	Move, Install & Verify Ant #23 on Site	2006-10-11	2006-10-24	2w																														
3.53	Accept Antenna #24 at OSF	2006-09-15	2006-09-15	0d																													2006-09-15	
<u>3.54</u>	<u>Prepare Antenna #24</u>	<u>2006-09-18</u>	<u>2006-11-24</u>	<u>10w</u>																														
3.54.1	Outfit & Verify Ant #24 at OSF	2006-09-18	2006-11-10	8w																														
3.54.2	Move, Install & Verify Ant #24 on Site	2006-11-13	2006-11-24	2w																														
3.55	Accept Antenna #25 at OSF	2006-10-16	2006-10-16	0d																													2006-10-16	
<u>3.56</u>	<u>Prepare Antenna #25</u>	<u>2006-10-16</u>	<u>2006-12-22</u>	<u>10w</u>																														
3.56.1	Outfit & Verify Ant #25 at OSF	2006-10-16	2006-12-08	8w																														
3.56.2	Move, Install & Verify Ant #25 on Site	2006-12-11	2006-12-22	2w																														
3.57	Accept Antenna #26 at OSF	2006-11-15	2006-11-15	0d																													2006-11-15	
<u>3.58</u>	<u>Prepare Antenna #26</u>	<u>2006-11-16</u>	<u>2007-01-24</u>	<u>10w</u>																														
3.58.1	Outfit & Verify Ant #26 at OSF	2006-11-16	2007-01-10	8w																														
3.58.2	Move, Install & Verify Ant #26 on Site	2007-01-11	2007-01-24	2w																														
3.59	Accept Antenna #27 at OSF	2006-12-15	2006-12-15	0d																													2006-12-15	
<u>3.60</u>	<u>Prepare Antenna #27</u>	<u>2006-12-18</u>	<u>2007-02-23</u>	<u>10w</u>																														
3.60.1	Outfit & Verify Ant #27 at OSF	2006-12-18	2007-02-09	8w																														
3.60.2	Move, Install & Verify Ant #27 on Site	2007-02-12	2007-02-23	2w																														
3.61	Accept Antenna #28 at OSF	2007-01-15	2007-01-15	0d																													2007-01-15	
<u>3.62</u>	<u>Prepare Antenna #28</u>	<u>2007-01-16</u>	<u>2007-03-26</u>	<u>10w</u>																														
3.62.1	Outfit & Verify Ant #28 at OSF	2007-01-16	2007-03-12	8w																														

Milestones: **bold type**
Summary Tasks: underline

Task

Milestone

Summary



MMA Construction Tasks

All Tasks selected

WBS	Task	Start	Finish	Duration	2001				2002				2003				2004				2005				2006				2007			
					Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
3.62.2	Move, Install & Verify Ant #28 on Site	2007-03-13	2007-03-26	2w																												
3.63	Accept Antenna #29 at OSF	2007-02-19	2007-02-19	0d																												
<u>3.64</u>	<u>Prepare Antenna #29</u>	<u>2007-02-20</u>	<u>2007-04-30</u>	<u>10w</u>																												
3.64.1	Outfit & Verify Ant #29 at OSF	2007-02-20	2007-04-16	8w																												
3.64.2	Move, Install & Verify Ant #29 on Site	2007-04-17	2007-04-30	2w																												
3.65	Accept Antenna #30 at OSF	2007-04-02	2007-04-02	0d																												
<u>3.66</u>	<u>Prepare Antenna #30</u>	<u>2007-04-03</u>	<u>2007-06-11</u>	<u>10w</u>																												
3.66.1	Outfit & Verify Ant #30 at OSF	2007-04-03	2007-05-28	8w																												
3.66.2	Move, Install & Verify Ant #30 on Site	2007-05-29	2007-06-11	2w																												
3.67	Accept Antenna #31 at OSF	2007-05-07	2007-05-07	0d																												
<u>3.68</u>	<u>Prepare Antenna #31</u>	<u>2007-05-08</u>	<u>2007-07-16</u>	<u>10w</u>																												
3.68.1	Outfit & Verify Ant #31 at OSF	2007-05-08	2007-07-02	8w																												
3.68.2	Move, Install and Verify Ant #31 on Site	2007-07-03	2007-07-16	2w																												
3.69	Accept Antenna #32 at OSF	2007-06-18	2007-06-18	0d																												
<u>3.70</u>	<u>Prepare Antenna #32</u>	<u>2007-06-19</u>	<u>2007-08-27</u>	<u>10w</u>																												
3.70.1	Outfit & Verify Ant #32 at OSF	2007-06-19	2007-08-13	8w																												
3.70.2	Move, Install & Verify Ant #32 on Site	2007-08-14	2007-08-27	2w																												
3.71	Accept Antenna #33 at OSF	2007-07-23	2007-07-23	0d																												
<u>3.72</u>	<u>Prepare Antenna #33</u>	<u>2007-07-24</u>	<u>2007-09-24</u>	<u>9w</u>																												
3.72.1	Outfit & Verify Ant #33 at OSF	2007-07-24	2007-09-10	7w																												
3.72.2	Move, Install and Verify Ant #33 on Site	2007-09-11	2007-09-24	2w																												
3.73	Accept Antenna #34 at OSF	2007-08-27	2007-08-27	0d																												
<u>3.74</u>	<u>Prepare Antenna #34</u>	<u>2007-08-28</u>	<u>2007-10-29</u>	<u>9w</u>																												
3.74.1	Outfit & Verify Ant #34 at OSF	2007-08-28	2007-10-15	7w																												
3.74.2	Move, Install and Verify Ant #34 on Site	2007-10-16	2007-10-29	2w																												
3.75	Accept Antenna #35 at OSF	2007-09-24	2007-09-24	0d																												
<u>3.76</u>	<u>Prepare Antenna #35</u>	<u>2007-09-24</u>	<u>2007-11-23</u>	<u>9w</u>																												
3.76.1	Outfit & Verify Ant #35 at OSF	2007-09-24	2007-11-09	7w																												
3.76.2	Move, Install & Verify Ant #35 on Site	2007-11-12	2007-11-23	2w																												
3.77	Accept Antenna #36 at OSF	2007-10-30	2007-10-30	0d																												

Milestones: **bold type**
Summary Tasks: underline

Task [blue bar] Milestone ▲

Summary [black bar]



MMA Construction Tasks

All Tasks selected

WBS	Task	Start	Finish	Duration	2001				2002				2003				2004				2005				2006				2007																			
					Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4																
<u>3.78</u>	<u>Prepare Antenna #36</u>	<u>2007-10-31</u>	<u>2008-01-01</u>	<u>9w</u>																																												
3.78.1	Outfit & Verify Ant #36 at OSF	2007-10-31	2007-12-18	7w																																												
3.78.2	Move, Install & Verify Ant #36 on Site	2007-12-19	2008-01-01	2w																																												
<u>3.79</u>	<u>Prepare Antenna #1</u>	<u>2005-09-01</u>	<u>2005-11-23</u>	<u>12w</u>																																												
3.79.1	Antenna #1 Reassembled at OSF	2005-09-01	2005-09-14	2w																																												
3.79.2	Outfit & Verify Ant #1 at OSF	2005-09-15	2005-11-09	8w																																												
3.79.3	Move, Install & Verify Ant #1 on Site	2005-11-10	2005-11-23	2w																																												
<u>3.80</u>	<u>Prepare Antenna #2</u>	<u>2005-12-15</u>	<u>2006-03-08</u>	<u>12w</u>																																												
3.80.1	Antenna #2 Reassembled at OSF	2005-12-15	2005-12-28	2w																																												
3.80.2	Outfit & Verify Ant #2 at OSF	2005-12-29	2006-02-22	8w																																												
3.80.3	Move, Install & Verify Ant #2 on Site	2006-02-23	2006-03-08	2w																																												
<u>3.81</u>	<u>Antenna Transporter</u>	<u>2003-04-01</u>	<u>2004-02-02</u>	<u>43.8w</u>																																												
3.81.1	Contract for Transporters #2, #3	2003-04-01	2003-04-01	0d																																												
3.81.2	Accept Transporters #2, #3 at OSF	2004-02-02	2004-02-02	0d																																												
4	Receivers	2001-01-01	2008-01-01	365.6w	[Summary Bar]																																											
<u>4.1</u>	<u>Receiver Package</u>	<u>2001-03-30</u>	<u>2007-10-01</u>	<u>339.2w</u>	[Summary Bar]																																											
<u>4.1.1</u>	<u>Prototype Production Receiver Cryogenics</u>	<u>2001-03-30</u>	<u>2001-11-30</u>	<u>35w</u>	[Summary Bar]																																											
4.1.1.1	CDR: Cryogenics Development	2001-03-30	2001-03-30	0w																																												
4.1.1.2	Construct & test prototype cryogenics	2001-04-30	2001-11-30	31w																																												
4.1.1.3	Deliver Prototype Cryogenics Subsystem	2001-11-30	2001-11-30	0w																																												
<u>4.1.2</u>	<u>Prototype Production Receiver Package</u>	<u>2001-07-02</u>	<u>2002-03-29</u>	<u>39w</u>	[Summary Bar]																																											
4.1.2.1	Prototype Receiver Package Integration	2001-07-02	2001-12-28	26w																																												
4.1.2.2	Prot. Rcvr. Pckg Lab Test & Evaluation	2001-12-31	2002-03-29	13w																																												
4.1.2.3	Complete Prototype MMA Receiver Package	2002-03-29	2002-03-29	0w																																												
4.1.3	MMA Rcvr Pckg Design Refinement	2002-07-01	2002-10-25	17w																																												
4.1.4	Documentation	2002-07-01	2002-10-25	17w																																												
4.1.5	Release MMA Receiver Pckg for manufacture	2002-10-25	2002-10-25	0w																																												
<u>4.1.6</u>	<u>Contract for Receiver Pckg Subassemblies</u>	<u>2002-11-01</u>	<u>2007-03-29</u>	<u>230.2w</u>	[Summary Bar]																																											
4.1.6.1	Machine Dewars	2002-11-01	2007-03-29	1151d																																												
4.1.6.2	Fabricate Cryogenics subsystems	2002-11-01	2007-03-29	1151d																																												

Milestones: **bold type**
Summary Tasks: underline

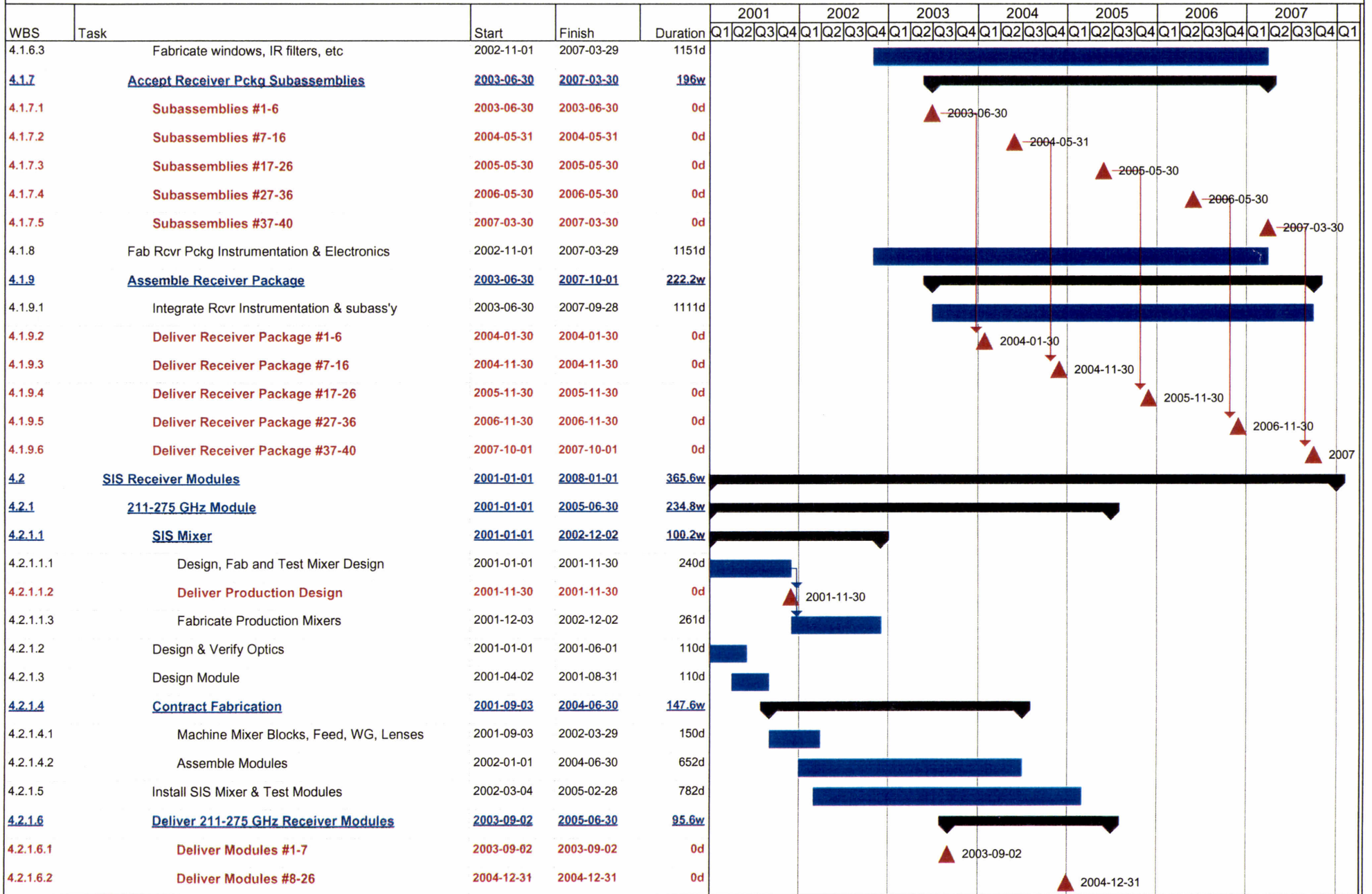
Task [Blue Bar] Milestone [Red Triangle]

Summary [Black Arrow]



MMA Construction Tasks

All Tasks selected



Milestones: **bold type**
 Summary Tasks: underline

Task Milestone Summary



MMA Construction Tasks
All Tasks selected

WBS	Task	Start	Finish	Duration	2001		2002		2003		2004		2005		2006		2007							
					Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
4.2.1.6.3	Deliver Modules #27-40	2005-06-30	2005-06-30	0d										▲	2005-06-30									
<u>4.2.2</u>	<u>602-720 GHz Module</u>	<u>2001-01-01</u>	<u>2005-06-30</u>	<u>234.8w</u>																				
<u>4.2.2.1</u>	<u>SIS Mixer</u>	<u>2001-01-01</u>	<u>2002-12-02</u>	<u>100.2w</u>																				
4.2.2.1.1	Design, Fabricate and Test Mixer Design	2001-01-01	2001-11-30	240d																				
4.2.2.1.2	Deliver Production Design	2001-11-30	2001-11-30	0d					▲	2001-11-30														
4.2.2.1.3	Fabricate Production Mixers	2001-12-03	2002-12-02	261d																				
4.2.2.2	Design & Verify Optics	2001-01-01	2001-06-01	110d																				
4.2.2.3	Design Module	2001-04-02	2001-08-30	109d																				
<u>4.2.2.4</u>	<u>Contract Fabrication</u>	<u>2001-09-03</u>	<u>2004-06-30</u>	<u>147.6w</u>																				
4.2.2.4.1	Machine Mixer Blocks, Feed, WG, Lenses	2001-09-03	2002-03-29	150d																				
4.2.2.4.2	Assemble Modules	2002-01-01	2004-06-30	652d																				
4.2.2.5	Install SIS Mixer and Test Modules	2002-04-02	2005-02-28	761d																				
<u>4.2.2.6</u>	<u>Deliver 602-720 GHz Receiver Modules</u>	<u>2003-09-02</u>	<u>2005-06-30</u>	<u>95.6w</u>																				
4.2.2.6.1	Deliver Modules #1-7	2003-09-02	2003-09-02	0d										▲	2003-09-02									
4.2.2.6.2	Deliver Modules #8-26	2004-12-31	2004-12-31	0d																				
4.2.2.6.3	Deliver Modules #27-40	2005-06-30	2005-06-30	0d																				
<u>4.2.3</u>	<u>275-370 GHz Receiver Module</u>	<u>2001-09-03</u>	<u>2006-05-31</u>	<u>247.6w</u>																				
<u>4.2.3.1</u>	<u>SIS Mixer</u>	<u>2001-12-03</u>	<u>2003-11-28</u>	<u>104w</u>																				
4.2.3.1.1	Design, Fabricate and Test Mixer Design	2001-12-03	2002-11-29	260d																				
4.2.3.1.2	Deliver Production Design	2002-11-29	2002-11-29	0d					▲	2002-11-29														
4.2.3.1.3	Fabricate Production Mixers	2002-12-02	2003-11-28	260d																				
4.2.3.2	Design & Verify Optics	2001-09-03	2002-04-01	151d																				
4.2.3.3	Design Module	2002-04-02	2002-09-02	110d																				
<u>4.2.3.4</u>	<u>Contract Fabrication</u>	<u>2002-04-01</u>	<u>2004-12-31</u>	<u>144w</u>																				
4.2.3.4.1	Machine Mixer Blocks, Feed, WG, Lenses	2002-04-01	2002-11-01	155d																				
4.2.3.4.2	Assemble Modules	2002-10-01	2004-12-31	589d																				
4.2.3.5	Install SIS Mixer and Test Modules	2003-03-03	2006-01-31	763d																				
<u>4.2.3.6</u>	<u>Deliver 275-370 GHz Receiver Module</u>	<u>2004-11-01</u>	<u>2006-05-31</u>	<u>82.6w</u>																				
4.2.3.6.1	Deliver Modules #1-5	2004-11-01	2004-11-01	0d																				
4.2.3.6.2	Deliver Modules #6-30	2006-01-02	2006-01-02	0d																				

Milestones: **bold type**
Summary Tasks: underline

Task Milestone

Summary



MMA Construction Tasks All Tasks selected

WBS	Task	Start	Finish	Duration	2001				2002				2003				2004				2005				2006				2007				
					Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	
4.2.5.6.3	Deliver Modules #31-40	2007-05-31	2007-05-31	0d																													▲ 2007-05-3
<u>4.2.6</u>	<u>385-500 GHz Receiver Module</u>	<u>2002-06-03</u>	<u>2007-08-31</u>	<u>274w</u>																													
<u>4.2.6.1</u>	<u>SIS Mixer</u>	<u>2003-03-03</u>	<u>2005-02-28</u>	<u>104.4w</u>																													
4.2.6.1.1	Design, Fabricate & Test Mixer Design	2003-03-03	2004-02-27	260d																													
4.2.6.1.2	Deliver Production Design	2004-02-27	2004-02-27	0d																													▲ -2004-02-27
4.2.6.1.3	Fabricate Production Mixers	2004-03-01	2005-02-28	262d																													
4.2.6.2	Design and Verify Optics	2002-06-03	2002-12-31	152d																													
4.2.6.3	Design Module	2002-09-02	2003-02-28	130d																													
<u>4.2.6.4</u>	<u>Contract Fabrication</u>	<u>2003-04-01</u>	<u>2005-12-30</u>	<u>144w</u>																													
4.2.6.4.1	Machine Mixer Blocks, Feed, WG, Lenses	2003-04-01	2003-10-31	154d																													
4.2.6.4.2	Assemble Modules	2003-10-01	2005-12-30	589d																													
4.2.6.5	Install SIS Mixer and Test	2004-09-01	2007-04-30	695d																													
<u>4.2.6.6</u>	<u>Deliver 385-500 GHz Receiver Modules</u>	<u>2005-10-31</u>	<u>2007-08-31</u>	<u>95.8w</u>																													
4.2.6.6.1	Deliver Modules #1-5	2005-10-31	2005-10-31	0d																													▲ 2005-10-31
4.2.6.6.2	Deliver Modules #6-30	2007-01-01	2007-01-01	0d																													▲ 2007-01-01
4.2.6.6.3	Deliver Modules #31-40	2007-08-31	2007-08-31	0d																													▲ 2007-0
<u>4.2.7</u>	<u>125-163 GHz Receiver Module</u>	<u>2003-06-02</u>	<u>2008-01-01</u>	<u>239.6w</u>																													
<u>4.2.7.1</u>	<u>SIS Mixer</u>	<u>2004-09-01</u>	<u>2006-08-31</u>	<u>104.6w</u>																													
4.2.7.1.1	Design, Fabricate & Test Mixer Design	2004-09-01	2005-08-31	262d																													
4.2.7.1.2	Deliver Production Design	2005-09-02	2005-09-02	0d																													▲ 2005-09-02
4.2.7.1.3	Fabricate Production Mixers	2005-09-01	2006-08-31	261d																													
4.2.7.2	Design & Verify Optics	2003-06-02	2003-12-31	153d																													
4.2.7.3	Design Module	2003-09-01	2004-02-27	130d																													
<u>4.2.7.4</u>	<u>Contract Fabrication</u>	<u>2004-04-01</u>	<u>2006-12-29</u>	<u>143.6w</u>																													
4.2.7.4.1	Machine Mixer Blocks, Feed, WG, Lenses	2004-04-01	2004-11-01	153d																													
4.2.7.4.2	Assemble Modules	2004-10-01	2006-12-29	587d																													
4.2.7.5	Install SIS Mixer and Test	2006-03-01	2007-12-31	479d																													
<u>4.2.7.6</u>	<u>Deliver 125-163 GHz Receiver Modules</u>	<u>2006-10-30</u>	<u>2008-01-01</u>	<u>61.4w</u>																													
4.2.7.6.1	Deliver 125-163 GHz Modules #1-5	2006-10-30	2006-10-30	0d																													▲ 2006-10-30
4.2.7.6.2	Deliver 125-163 GHz Modules #6-30	2007-10-01	2007-10-01	0d																													▲ 2007

Milestones: **bold type**
Summary Tasks: underline

Task Milestone ▲ Summary



MMA Construction Tasks

All Tasks selected

WBS	Task	Start	Finish	Duration	2001				2002				2003				2004				2005				2006				2007			
					Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
5.1.3	Procure/Fab Field Prototypes	2001-08-01	2002-01-29	26w																												
5.1.4	Deliver: LO Ref Field Prototypes	2002-03-01	2002-03-01	0w																												
5.1.5	Field Prototype testing and Design Refinement	2002-01-30	2002-07-30	26w																												
5.1.6	Preproduction Review	2002-07-30	2002-07-30	0w																												
5.1.7	Final Documentation and Design Modifications	2002-07-31	2002-09-03	5w																												
5.1.8	Release for Manufacture	2002-09-03	2002-09-03	0w																												
<u>5.2</u>	<u>LO Reference: Production System</u>	<u>2001-06-01</u>	<u>2008-01-01</u>	<u>343.8w</u>																												
5.1.1	Production test and lab equipment	2001-06-01	2008-01-01	343.8w																												
5.1.2	H-maser Frequency Standard (& Rb)	2002-09-05	2003-09-03	52w																												
5.1.3	8 GHz PL Oscillator & Distributor	2002-09-05	2008-01-01	278w																												
5.1.4	10 GHz PL Oscillator & Distributor	2002-09-05	2008-01-01	278w																												
5.1.5	12 GHz PL Oscillator & Distributor	2002-09-05	2008-01-01	278w																												
5.1.6	14 GHz PL Oscillator & Distributor	2002-09-05	2008-01-01	278w																												
5.1.7	3.2-5.2 GHz Synthesizer	2002-09-05	2008-01-01	278w																												
5.1.8	3.2 -5.2 GHz PLO and Fringe Generator	2002-09-05	2008-01-01	278w																												
5.1.9	Sampler Clock 4 GHz PL Osc & Distributor	2002-09-05	2004-03-03	78w																												
5.1.10	LO Ref Generator	2002-09-05	2004-03-03	78w																												
5.1.11	LO Ref Distributor - Control Bldg	2002-09-05	2004-03-03	78w																												
5.1.12	Microwave Round-trip Phase Measurement	2002-09-05	2008-01-01	278w																												
5.1.13	10-15 GHz Frequency Synthesizer	2002-09-05	2008-01-01	278w																												
5.1.14	First LO Fringe Generator	2002-09-05	2008-01-01	278w																												
5.1.15	16 GHz PL Oscillator	2002-09-05	2008-01-01	278w																												
5.1.16	26 GHz PL Oscillator	2002-09-05	2008-01-01	278w																												
5.1.17	LO Ref Distributor - Antenna	2002-09-05	2008-01-01	278w																												
5.1.18	VXCO Clean-up Loop	2002-09-05	2008-01-01	278w																												
5.1.19	Power supply module	2002-09-05	2008-01-01	278w																												
5.1.20	Bins / Racks (assemble and test)	2002-09-05	2008-01-01	278w																												
<u>5.3</u>	<u>Millimeter LO Drivers</u>	<u>2001-01-01</u>	<u>2007-05-31</u>	<u>335w</u>																												
5.3.1	Design and System Integration	2001-01-01	2006-12-28	1565d																												
5.3.2	72-95 GHz Source	2001-01-01	2004-12-31	208.8w																												

Milestones: **bold type**
Summary Tasks: underline

Task Milestone

Summary



MMA Construction Tasks

All Tasks selected

WBS	Task	Start	Finish	Duration	2001				2002				2003				2004				2005				2006				2007			
					Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
5.3.2.1	<u>Contract Procurement and Fabrication</u>	2001-01-01	2003-05-31	126w																												
5.3.2.1.1	YIG-tuned Oscillator	2001-01-01	2003-05-31	630d																												
5.3.2.1.2	18.00 - 23.75 GHz 10 db Amplifier	2001-01-01	2003-05-30	630d																												
5.3.2.1.3	18.00 - 23.75 GHz x2 Multiplier	2001-01-01	2003-05-30	630d																												
5.3.2.1.4	36.0 - 47.5 GHz 10 db Amplifier	2001-01-01	2003-05-30	630d																												
5.3.2.1.5	36.0 - 47.5 GHz x2 Multiplier	2001-01-01	2003-05-30	630d																												
5.3.2.1.6	Mount and Tuning circuitry	2001-01-01	2003-05-30	630d																												
5.3.2.2	Assembly and Test	2002-03-01	2004-11-30	718d																												
5.3.2.3	<u>Deliver 72 - 95 GHz LO Sources</u>	2002-12-31	2004-12-31	104.6w																												
5.3.2.3.1	Deliver Modules #1-6	2002-12-31	2002-12-31	0d																												
5.3.2.3.2	Deliver Modules #7-24	2003-12-31	2003-12-31	0d																												
5.3.2.3.3	Deliver Modules #25-40	2004-12-31	2004-12-31	0d																												
5.3.3	<u>100-120 GHz Source</u>	2001-01-01	2004-12-31	208.8w																												
5.3.3.1	<u>Contract Procurement and Fabrication</u>	2001-01-01	2003-05-30	126w																												
5.3.3.1.1	YIG-tuned Oscillator	2001-01-01	2003-05-30	630d																												
5.3.3.1.2	25.00 - 30.00 GHz 10 db Amplifier	2001-01-01	2003-05-30	630d																												
5.3.3.1.3	15.00 - 30.00 GHz x2 Multiplier	2001-01-01	2003-05-30	630d																												
5.3.3.1.4	50.0 - 60.0 GHz 10 db Amplifier	2001-01-01	2003-05-30	630d																												
5.3.3.1.5	50-60 GHz x2 Multiplier	2001-01-01	2003-05-30	630d																												
5.3.3.1.6	Mount and Tuning circuitry	2001-01-01	2003-05-30	630d																												
5.3.3.2	Assembly and Test	2002-06-03	2004-11-30	652d																												
5.3.3.3	<u>Deliver 100 - 120 GHz LO Sources</u>	2002-12-31	2004-12-31	104.6w																												
5.3.3.3.1	Deliver Modules #1-3	2002-12-31	2002-12-31	0d																												
5.3.3.3.2	Deliver Modules #4-21	2003-12-31	2003-12-31	0d																												
5.3.3.3.3	Deliver Modules #22-40	2004-12-31	2004-12-31	0d																												
5.3.4	<u>87 - 108 GHz Source</u>	2003-01-01	2007-05-31	230.4w																												
5.3.4.1	<u>Contract Procurement and Fabrication</u>	2003-01-01	2005-05-30	126w																												
5.3.4.1.1	YIG-tuned Oscillator	2003-01-01	2005-05-30	630d																												
5.3.4.1.2	21.75-27.00 GHz 10 db Amplifier	2003-01-01	2005-05-30	630d																												
5.3.4.1.3	21.75-27.00 GHz x2 Multiplier	2003-01-01	2005-05-30	630d																												

Milestones: **bold type**
Summary Tasks: underline

Task Milestone

Summary



MMA Construction Tasks
All Tasks selected

Table with columns: WBS, Task, Start, Finish, Duration, and quarterly breakdowns for years 2001 through 2007. Tasks include 43.5-54.0 GHz 10 db Amplifier, 65-85 GHz Source, and Millimeter LO Multiplier Chains.

Milestones: bold type
Summary Tasks: underline

Task [blue bar] Milestone [triangle] Summary [thick black bar]



MMA Construction Tasks
All Tasks selected

WBS	Task	Start	Finish	Duration	2001				2002				2003				2004				2005				2006				2007			
					Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
5.4.2.2	Assemble Multiplier and Test	2002-06-03	2004-06-30	543d																												
5.4.2.3	Integrate Source and Multiplier; test	2002-09-02	2004-12-31	610d																												
<u>5.4.2.4</u>	<u>Deliver 211-275 GHz Rcvr LO Modules</u>	<u>2002-12-31</u>	<u>2004-12-31</u>	<u>104.6w</u>																												
5.4.2.4.1	Deliver Modules #1-3	2002-12-31	2002-12-31	0d																												
5.4.2.4.2	Deliver Modules #4-21	2003-12-31	2003-12-31	0d																												
5.4.2.4.3	Deliver Modules #22-40	2004-12-31	2004-12-31	0d																												
<u>5.4.3</u>	<u>602 - 720 GHz Receiver LO</u>	<u>2002-01-01</u>	<u>2005-05-02</u>	<u>174w</u>																												
<u>5.4.3.1</u>	<u>Contract Fabrication</u>	<u>2002-01-01</u>	<u>2003-05-30</u>	<u>73.8w</u>																												
5.4.3.1.1	X2 Diode for 100-120 GHz Source	2002-01-01	2002-08-30	174d																												
5.4.3.1.2	X3 Diode for 200-240 GHz Input	2002-01-01	2002-08-30	174d																												
5.4.3.1.3	Machine Mount	2002-04-01	2002-11-29	175d																												
5.4.3.1.4	Bias and Control circuits	2002-07-01	2003-05-30	240d																												
5.4.3.2	Assemble Multipliers and Test	2002-09-02	2004-11-01	566d																												
5.4.3.3	Integrate Source and Multipliers; test	2002-11-01	2005-02-28	608d																												
<u>5.4.3.4</u>	<u>Deliver 602-720 GHz Rcvr LO Modules</u>	<u>2003-04-01</u>	<u>2005-05-02</u>	<u>109w</u>																												
5.4.3.4.1	Deliver Modules #1-6	2003-04-01	2003-04-01	0d																												
5.4.3.4.2	Deliver Modules #7-18	2003-12-31	2003-12-31	0d																												
5.4.3.4.3	Deliver Modules #19-34	2004-12-31	2004-12-31	0d																												
5.4.3.4.4	Deliver Modules #35-40	2005-05-02	2005-05-02	0d																												
<u>5.4.4</u>	<u>275 - 370 GHz Receiver LO</u>	<u>2002-04-01</u>	<u>2006-01-02</u>	<u>196.2w</u>																												
<u>5.4.4.1</u>	<u>Contract Fabrication</u>	<u>2002-04-01</u>	<u>2003-08-29</u>	<u>74w</u>																												
5.4.4.1.1	X2 Diode for 72-95 GHz Source	2002-04-01	2002-11-29	175d																												
5.4.4.1.2	X2 Diode for 144-190 GHz Input	2002-04-01	2002-11-29	175d																												
5.4.4.1.3	Machine Mount	2002-07-01	2003-02-28	175d																												
5.4.4.1.4	Bias and Control Circuits	2002-10-01	2003-08-29	239d																												
5.4.4.2	Assemble Multipliers and Test	2003-02-03	2005-03-29	563d																												
5.4.4.3	Integrate Source and Multipliers; test	2003-04-01	2005-04-28	544d																												
<u>5.4.4.4</u>	<u>Deliver 275-370 GHz Rcvr LO Modules</u>	<u>2003-09-01</u>	<u>2006-01-02</u>	<u>122.2w</u>																												
5.4.4.4.1	Deliver Modules #1-6	2003-09-01	2003-09-01	0d																												
5.4.4.4.2	Deliver Modules #7-27	2004-12-31	2004-12-31	0d																												

Milestones: **bold type**
Summary Tasks: underline

Task Milestone

Summary



MMA Construction Tasks
All Tasks selected

WBS	Task	Start	Finish	Duration	2001				2002				2003				2004				2005				2006				2007											
					Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4								
5.4.4.4.3	Deliver Modules #28-40	2006-01-02	2006-01-02	0d																																				
5.4.5	<u>163 - 211 GHz Receiver LO</u>	2003-04-01	2006-10-02	183w																																				
5.4.5.1	<u>Contract Fabrication</u>	2003-04-01	2004-08-31	74.2w																																				
5.4.5.1.1	X2 Diode for 87-108 GHz Source	2003-04-01	2003-11-28	174d																																				
5.4.5.1.2	Machine Mount	2003-07-01	2004-02-27	174d																																				
5.4.5.1.3	Bias and Control Circuits	2003-10-01	2004-08-31	240d																																				
5.4.5.2	Assemble Multiplier and Test	2004-01-01	2006-02-27	564d																																				
5.4.5.3	Integrate Source and Multiplier; test	2004-03-01	2006-05-30	588d																																				
5.4.5.4	<u>Deliver 163 - 211 GHz Rcvr LO Modules</u>	2004-12-31	2006-10-02	91.4w																																				
5.4.5.4.1	Deliver Modules #1-6	2004-12-31	2004-12-31	0d																																				
5.4.5.4.2	Deliver Modules #7-24	2006-01-02	2006-01-02	0d																																				
5.4.5.4.3	Deliver Modules #25-40	2006-10-02	2006-10-02	0d																																				
5.4.6	<u>385 - 500 GHz Receiver LO</u>	2003-04-01	2006-10-02	183w																																				
5.4.6.1	<u>Contract Fabrication</u>	2003-04-01	2004-08-31	74.2w																																				
5.4.6.1.1	X3 Diode for 65-85 GHz Source	2003-04-01	2003-11-28	174d																																				
5.4.6.1.2	X2 Diode for 130-170 GHz Input	2003-04-01	2003-11-28	174d																																				
5.4.6.1.3	Machine Mount	2003-07-01	2004-02-27	174d																																				
5.4.6.1.4	Bias and Control Circuits	2003-10-01	2004-08-31	240d																																				
5.4.6.2	Assemble Multiplier and test	2004-01-01	2006-02-27	564d																																				
5.4.6.3	Integrate source and Multiplier; test	2004-03-01	2006-05-30	588d																																				
5.4.6.4	<u>Deliver 385-500 GHz Rcvr LO Modules</u>	2004-12-31	2006-10-02	91.4w																																				
5.4.6.4.1	Deliver Modules #1-6	2004-12-31	2004-12-31	0d																																				
5.4.6.4.2	Deliver Modules #7-24	2006-01-02	2006-01-02	0d																																				
5.4.6.4.3	Deliver Modules #25-40	2006-10-02	2006-10-02	0d																																				
5.4.7	<u>125 - 163 GHz Receiver LO</u>	2003-10-01	2007-04-02	182.8w																																				
5.4.7.1	<u>Contract Fabrication</u>	2003-10-01	2005-02-25	73.8w																																				
5.4.7.1.1	X2 Diode for 65 - 85 GHz Source	2003-10-01	2004-05-31	174d																																				
5.4.7.1.2	Machine Mount	2004-01-01	2004-08-31	174d																																				
5.4.7.1.3	Bias and Control Circuits	2004-04-01	2005-02-25	238d																																				
5.4.7.2	Assemble Multiplier and test	2004-07-01	2006-08-30	566d																																				

Milestones: **bold type**
 Summary Tasks: underline
 Task Milestone Summary



MMA Construction Tasks

All Tasks selected

WBS	Task	Start	Finish	Duration	2001				2002				2003				2004				2005				2006				2007			
					Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
5.4.7.3	Integrate Source and Multiplier; test	2004-09-01	2006-11-29	587d																												
<u>5.4.7.4</u>	<u>Deliver 125-163 GHz Rcvr LO Modules</u>	<u>2005-04-01</u>	<u>2007-04-02</u>	<u>104.2w</u>																												
5.4.7.4.1	Deliver Modules #1-6	2005-04-01	2005-04-01	0d																												
5.4.7.4.2	Deliver Modules #7-18	2006-01-02	2006-01-02	0d																												
5.4.7.4.3	Deliver Modules #19-34	2007-01-01	2007-01-01	0d																												
5.4.7.4.4	Deliver Modules #35-40	2007-04-02	2007-04-02	0d																												
<u>5.4.8</u>	<u>33-45 GHz Receiver LO</u>	<u>2001-01-01</u>	<u>2002-12-31</u>	<u>104.4w</u>																												
5.4.8.1	Design & Fab Selection & Coupling from Sources	2001-01-01	2002-12-31	522d																												
6	IF System	2001-01-31	2008-01-01	361.2w																												
<u>6.1</u>	<u>IF System: Prototype Systems</u>	<u>2001-01-31</u>	<u>2002-09-03</u>	<u>83w</u>																												
6.1.1	Deliver (Bench) Prototype IF System	2001-01-31	2001-01-31	0w																												
6.1.2	Testing and Design Refinement	2001-01-31	2001-07-31	26w																												
6.1.3	Procure/Fab Field Prototypes	2001-08-01	2002-01-29	26w																												
6.1.4	Deliver IF Field Prototypes to Test Interfeometer	2002-03-01	2002-03-01	0w																												
6.1.5	Field Prototype testing and Design Refinement	2002-01-30	2002-07-30	26w																												
6.1.6	Preproduction Review	2002-07-30	2002-07-30	0w																												
6.1.7	Final Documentation and Design Modifications	2002-07-31	2002-09-03	5w																												
6.1.8	Release for Manufacture	2002-09-03	2002-09-03	0w																												
6.2	Production test and lab equipment	2001-05-31	2008-01-01	344w																												
6.3	IF Multiplexer	2002-09-05	2008-01-01	278w																												
6.4	IF Demultiplexer	2002-09-05	2008-01-01	278w																												
6.5	IF Matrix Switch	2002-09-05	2008-01-01	278w																												
6.6	Baseband Converter	2002-09-05	2008-01-01	278w																												
6.7	Power supply module	2002-09-05	2008-01-01	278w																												
6.8	Bins / Racks (assemble and test)	2002-09-05	2008-01-01	278w																												
7	Optical Fiber System	2001-01-31	2008-01-01	361.2w																												
<u>7.1</u>	<u>Optical Fiber System: Prototype Systems</u>	<u>2001-01-31</u>	<u>2002-09-03</u>	<u>83w</u>																												
7.1.1	Deliver (Bench) Prototype FO System	2001-01-31	2001-01-31	0w																												
7.1.2	Testing and Design Refinement	2001-01-31	2001-07-31	26w																												
7.1.3	Procure/Fab Field Prototypes	2001-08-01	2002-01-29	26w																												

Milestones: **bold type**
 Summary Tasks: underline

Task

Milestone

Summary



MMA Construction Tasks
All Tasks selected

WBS	Task	Start	Finish	Duration	2001		2002				2003				2004				2005				2006				2007						
					Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	
7.1.4	Deliver FO Field Prototypes to Test Interfeometer	2002-03-01	2002-03-01	0w					▲																								
7.1.5	Field Prototype testing and Design Refinement	2002-01-30	2002-07-30	26w					■	■	■	■																					
7.1.6	Preproduction Review	2002-07-30	2002-07-30	0w						▲																							
7.1.7	Final Documentation and Design Modifications	2002-07-31	2002-09-03	5w					■																								
7.1.8	Release for Manufacture	2002-09-03	2002-09-03	0w							▲																						
7.1	Production test and lab equipment	2001-06-01	2008-01-01	343.8w	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	
7.2	IF TX / RX	2002-09-05	2008-01-01	278w						■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	
7.3	LO Reference TX / RX	2002-09-05	2008-01-01	278w						■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	
7.4	Microwave Round-trip Phase TX / RX	2002-09-05	2008-01-01	278w						■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	
7.5	Monitor / Control TX / RX	2002-09-05	2008-01-01	278w						■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	
7.6	Power supply module	2002-09-05	2008-01-01	278w						■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	
7.7	Bins / Racks (assemble and test)	2002-09-05	2008-01-01	278w						■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	
8	Correlator	2001-01-01	2008-01-01	365.6w	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
8.1	Digital Sampler, 4 GHz	2001-01-01	2003-06-30	130.2w	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
8.1.1	Refine Design	2001-01-01	2002-01-02	263d	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
8.1.2	Release Digital Sampler for Manufacture	2002-01-02	2002-01-02	0w						▲																							
8.1.3	Contract Materials	2002-01-03	2002-04-02	64d						■																							
8.1.4	Assembly	2002-07-01	2003-01-31	155d						■	■	■	■																				
8.1.5	Validation and Delivery	2002-11-01	2003-06-30	172d							■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	
8.2	Digital FIR Filter	2001-03-01	2003-12-26	147.4w	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
8.2.1	Prototype testing on Test Interferometer	2001-03-01	2001-08-29	26w	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
8.2.2	Design Refinement	2001-08-30	2001-10-24	8w						■	■	■	■																				
8.2.3	Release FIR Filter for manufacture	2001-10-24	2001-10-24	0w							▲																						
8.2.4	Chip Fabrication	2001-10-25	2002-07-24	39w						■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
8.2.5	Assembly	2002-07-25	2003-07-23	52w							■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
8.2.6	Validation and Delivery	2003-03-31	2003-12-26	39w								■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
8.3	Custom Boards	2001-07-02	2002-01-11	28w	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
8.3.1	Correlator Board	2001-07-02	2002-01-11	28w	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
8.3.1.1	Prototype assembly	2001-07-02	2001-07-27	4w	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
8.3.1.2	Prototype test	2001-07-30	2001-09-21	8w	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		

Milestones: **bold type**
Summary Tasks: underline

Task ■ Milestone ▲

Summary ▬



MMA Construction Tasks

All Tasks selected

WBS	Task	Start	Finish	Duration	2001		2002				2003				2004				2005				2006				2007			
					Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2
8.3.1.3	Design modifications	2001-09-24	2001-10-19	4w																										
8.3.1.4	Fab, assemble and test with design mods	2001-10-22	2002-01-11	12w																										
8.4	<u>Correlator Chip</u>	<u>2001-01-08</u>	<u>2002-07-05</u>	<u>78w</u>																										
8.4.1	Prototype chip fabrication	2001-01-08	2001-07-01	25w																										
8.4.2	Prototype chip test	2001-07-02	2001-08-24	8w																										
8.4.3	Design modifications	2001-09-24	2002-01-11	16w																										
8.4.4	Fabricate and test design mods	2002-01-14	2002-04-12	13w																										
8.4.5	Fabricate production run	2002-04-15	2002-07-05	12w																										
8.5	<u>Racks</u>	<u>2001-01-01</u>	<u>2001-07-13</u>	<u>28w</u>																										
8.5.1	Design control wiring	2001-01-01	2001-01-26	4w																										
8.5.2	Design signal wiring	2001-01-29	2001-02-23	4w																										
8.5.3	Order parts	2001-02-26	2001-04-20	8w																										
8.5.4	Assemble prototypes	2001-04-23	2001-07-13	12w																										
8.6	Software	2001-01-01	2003-05-30	126w																										
8.7	<u>Prototype Correlator Production</u>	<u>2002-03-07</u>	<u>2003-05-30</u>	<u>64.4w</u>																										
8.7.1	Order parts	2002-03-07	2002-05-01	8w																										
8.7.2	Assemble	2002-07-08	2002-11-08	18w																										
8.7.3	Test	2002-11-11	2003-03-28	20w																										
8.7.4	Deliver Prototype Correlator to VLA site	2003-05-30	2003-05-30	0d																										
8.8	<u>Site Correlator Production</u>	<u>2002-11-11</u>	<u>2006-10-05</u>	<u>204w</u>																										
8.8.1	<u>First 1/4 correlator</u>	<u>2002-11-11</u>	<u>2004-06-18</u>	<u>84w</u>																										
8.8.1.1	Determine configuration	2002-11-11	2002-12-06	4w																										
8.8.1.2	Order parts	2002-12-09	2003-02-28	12w																										
8.8.1.3	Assemble	2003-03-03	2003-09-12	28w																										
8.8.1.4	Test	2003-09-15	2004-06-18	40w																										
8.8.1.5	Deliver 1/4 Correlator to MMA site	2004-06-18	2004-06-18	0d																										
8.8.2	<u>Second 1/4 correlator</u>	<u>2003-09-15</u>	<u>2005-03-24</u>	<u>80w</u>																										
8.8.2.1	Order parts	2003-09-15	2003-12-05	12w																										
8.8.2.2	Assemble	2003-12-08	2004-06-18	28w																										
8.8.2.3	Test	2004-06-21	2005-03-24	40w																										

Milestones: **bold type**
Summary Tasks: underline

Task

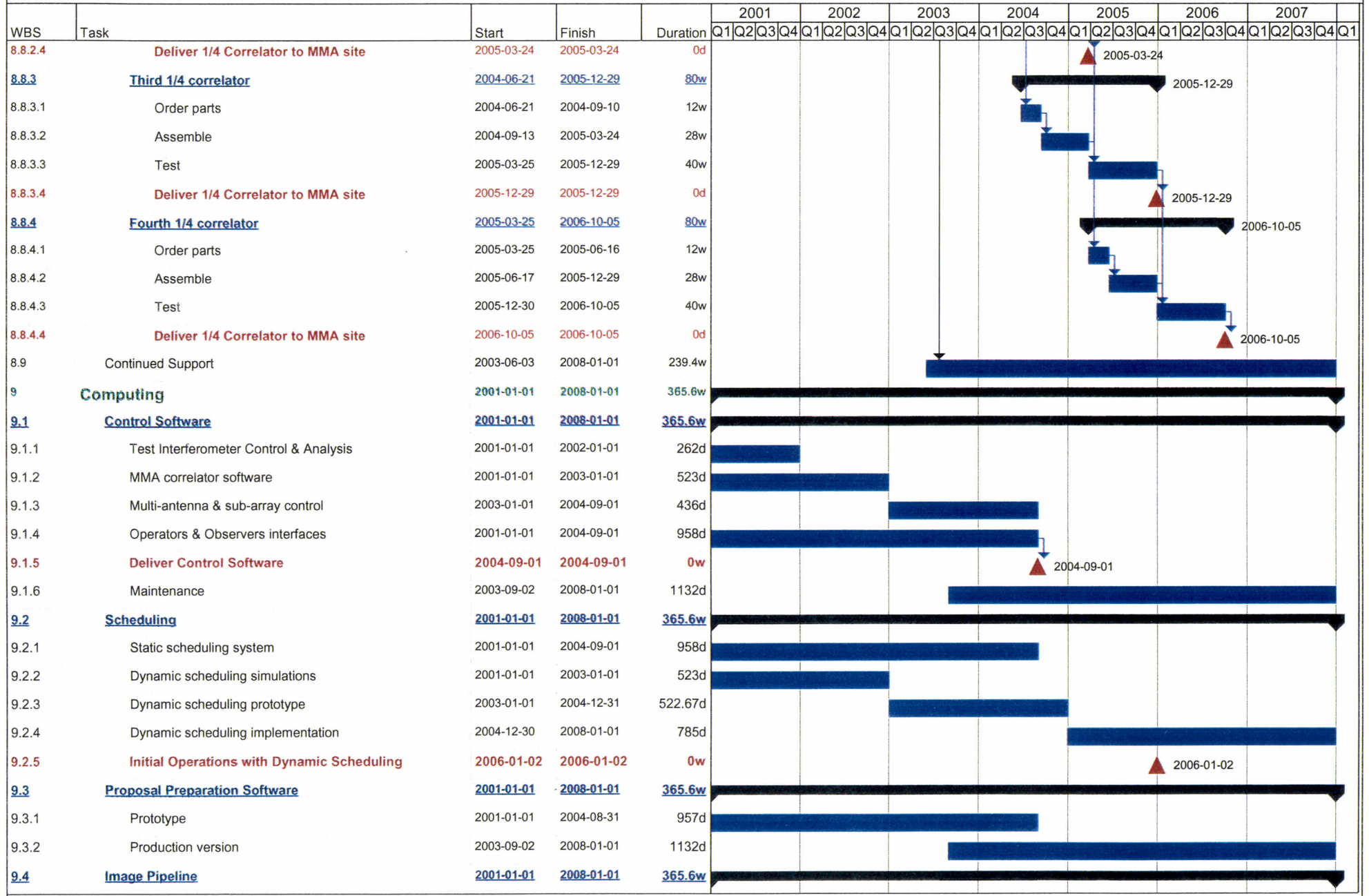
Milestone

Summary



MMA Construction Tasks

All Tasks selected



Milestones: **bold type**
Summary Tasks: underline

Task Milestone Summary



MMA Construction Tasks

All Tasks selected

WBS	Task	Start	Finish	Duration	2001				2002				2003				2004				2005				2006				2007			
					Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
9.4.1	Automated calibration & imaging heuristics	2001-01-01	2003-01-01	523d	█																											
9.4.2	Prototype image pipeline	2003-01-01	2004-01-01	262d					█																							
9.4.3	Parallelization studies and implementation	2004-01-01	2006-01-01	523d									█																			
9.4.4	Initial Image Pipeline Operations	2006-06-01	2006-06-01	0w																	▲ 2006-06-01											
9.4.5	Production image pipeline	2004-12-30	2008-01-01	785d													█															
<u>9.5</u>	<u>Archiving</u>	<u>2001-01-01</u>	<u>2008-01-01</u>	<u>365.6w</u>	█																											
9.5.1	Prototype distributed archive	2001-01-01	2004-01-01	784d	█																											
9.5.2	Evaluate storage hardware	2007-01-01	2007-06-01	110d																	█											
9.5.3	Production archive	2002-12-31	2008-01-01	1307d					█																							
9.5.4	Data Archive operational	2005-01-01	2005-01-01	0w													▲ 2005-01-01															
<u>9.6</u>	<u>Post-processing</u>	<u>2001-01-01</u>	<u>2008-01-01</u>	<u>365.6w</u>	█																											
9.6.1	Define MMA Data formats	2002-01-03	2003-01-01	260d					█																							
9.6.2	MMA filler & format conversions	2003-01-01	2004-09-01	436d					█																							
9.6.3	MMA-specific calibrations	2001-01-01	2004-09-01	958d	█																											
9.6.4	MMA Post-processing begins	2004-09-01	2004-09-01	0w									▲ 2004-09-01																			
9.6.5	Maintenance	2003-09-01	2008-01-01	1133d									█																			
10	System Integration	2001-01-01	2008-01-01	365.6w	█																											
<u>10.4</u>	<u>Test Interferometer Site Preparation</u>	<u>2001-01-01</u>	<u>2001-04-30</u>	<u>17.2w</u>	█																											
10.4.1	Complete Office and Lab Space Preparation	2001-01-01	2001-03-30	13w	█																											
10.4.2	Cabling	2001-02-05	2001-04-27	12w	█																											
10.4.3	Test Interferometer Site Complete	2001-04-30	2001-04-30	0d																	▲ 2001-04-30											
<u>10.10.4</u>	<u>Prototype Antenna Outfitting</u>	<u>2001-06-01</u>	<u>2001-09-03</u>	<u>13.2w</u>	█																											
10.10.4.1	Cabling	2001-06-01	2001-07-05	5w	█																											
10.10.4.2	Instrumentation	2001-07-06	2001-08-30	8w	█																											
10.10.4.3	Eval. Rcvr. #1 / Ant. #1 Integration	2001-07-06	2001-08-30	8w	█																											
10.10.4.4	Antenna #1 Outfitting Complete	2001-09-03	2001-09-03	0d																	▲ 2001-09-03											
10.10.5	Integration Holography System/Antenna	2001-09-03	2001-10-26	8w	█																											
10.10.6	Integration Metrology/Antenna	2001-09-03	2001-10-26	8w	█																											
10.10.7	Antenna #1 Integration & Testing	2001-09-03	2003-02-28	78w	█																											
10.10.8	Prot. Rcvr. Test & Evaluation	2002-04-01	2002-06-28	13w					█																							

Milestones: **bold type**
 Summary Tasks: underline

Task █

Milestone ▲

Summary █



MMA Construction Tasks

All Tasks selected

WBS	Task	Start	Finish	Duration	2001				2002				2003				2004				2005				2006				2007			
					Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
<u>10.10.9</u>	Antenna #2 Outfitting	2001-01-01	2002-04-01	65w																												
10.10.9.1	Cabling	2001-01-01	2001-02-02	5w																												
10.10.9.2	Instrumentation	2001-02-05	2001-03-30	8w																												
10.10.9.3	Eval. Rcvr. #2 / Ant. #2 Integration	2001-06-01	2001-07-26	8w																												
10.10.9.4	Antenna #2 Outfitting Complete	2002-04-01	2002-04-01	0d																												
<u>10.11</u>	Test Interferometer	2002-04-01	2005-04-01	157.2w																												
<u>10.11.1</u>	Antenna Evaluation & Characterization	2002-04-01	2003-05-30	61w																												
10.11.1.1	Antenna Verification	2002-04-01	2003-05-30	305d																												
10.11.1.4	Holography	2002-04-01	2002-08-30	110d																												
10.11.1.5	Beam and Sidelobes	2002-04-01	2002-08-30	110d																												
10.11.1.6	Gain vs. Elevation: Spillover Temp	2002-04-01	2002-08-30	110d																												
10.11.1.7	Effect of Sun in & Near the Beam	2002-04-01	2002-08-30	110d																												
10.11.2	Engineering Recommendations re Prod. Ant.	2002-09-30	2002-09-30	0d																												
10.11.3	Revise Interface Specifications	2002-10-01	2002-12-31	66d																												
<u>10.11.5</u>	Operations Personnel Training	2002-09-02	2005-04-01	135.2w																												
10.11.5.1	Recruit Initial Chile Ops Staff	2002-09-02	2003-03-28	30w																												
10.11.5.2	Array Operations	2003-01-01	2004-12-28	104w																												
10.11.5.3	Engineering Maintenance	2003-01-01	2004-12-28	104w																												
10.11.5.4	Scientific Support & Analysis	2003-01-01	2004-12-28	104w																												
10.12.2	Relocate Ops Staff to Chile	2005-01-01	2005-04-01	66d																												
10.8.4.6	Start On-site Operations	2005-04-01	2005-04-01	0w																												
<u>10.12</u>	Disassemble Test Interferometer	2005-01-03	2005-05-31	21.4w																												
10.12.1	Prepare & Ship Antenna #1, #2	2005-01-03	2005-03-31	64d																												
10.12.3	Restore Facilities at VLA Site	2005-01-03	2005-05-31	107d																												
10.13	On Site System Integration	2003-01-03	2008-01-01	260.8w																												
11	Calibration and Imaging	2001-01-01	2008-01-01	365.6w																												
<u>11.1</u>	Radiometric Phase Design & Prototype	2001-01-01	2002-08-07	83.6w																												
11.1.1	Complete 183GHz Phase Mon Prototype	2001-01-01	2001-02-02	5w																												
11.1.2	Demo 183 GHz Phase Monitor Radiometer on-Site	2001-02-05	2002-02-06	263d																												
11.1.3	Design Refinement	2002-02-07	2002-08-07	26w																												

Milestones: **bold type**
 Summary Tasks: underline

Task Milestone

Summary



MMA Construction Tasks

All Tasks selected

WBS	Task	Start	Finish	Duration	2001		2002				2003				2004				2005				2006				2007									
					Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4				
11.1.4	Release Phase Mon Radiometer for manufacture	2002-08-07	2002-08-07	0w																																
11.2	<u>Production Fab of Phase Monitor Radiometer</u>	2002-08-08	2008-01-01	282w																																
11.2.1	<u>Contract Subassembly Fabrication</u>	2002-08-08	2004-08-04	104w																																
11.2.1.1	Radiometer & Local Oscillator	2002-08-08	2004-08-04	104w																																
11.2.1.2	Spectrometer	2002-08-08	2004-08-04	104w																																
11.2.1.3	Feed, Window, lens, instrumentation	2002-08-08	2004-08-04	104w																																
11.2.1.4	M/C Interface	2002-08-08	2003-07-31	51.2w																																
11.2.2	Assembly & Test	2003-04-01	2004-12-31	459d																																
11.2.3	Deliver Production Radiometers	2003-06-30	2005-06-29	524d																																
11.2.4	Integration in Receiver Package	2003-07-01	2007-06-22	208w																																
11.2.5	Verification on-Site	2004-07-01	2008-01-01	183w																																
11.3	<u>Production Fabrication of Dual-load Amp Cal Sys</u>	2001-06-01	2008-01-01	343.8w																																
11.3.1	Design Refinement	2001-06-01	2002-02-28	39w																																
11.3.2	Release Phase Mon Radiometer for manufacture	2002-02-28	2002-02-28	0w																																
11.3.3	<u>Contract Subassembly</u>	2002-06-03	2003-06-30	56.2w																																
11.3.3.1	Machining	2002-06-03	2003-03-31	216d																																
11.3.3.2	Load Fabrication	2002-06-03	2003-06-30	281d																																
11.3.3.3	Motors, Servo	2002-06-03	2003-06-30	281d																																
11.3.3.4	M/C Interface	2002-06-03	2003-03-31	216d																																
11.3.4	Assembly & Test	2003-03-03	2003-08-29	130d																																
11.3.5	Integration on Production Antennas	2004-04-02	2008-01-01	979d																																
11.4	Imaging Studies & Project Support	2001-01-01	2008-01-01	1828d																																
11.5	Imaging Algorithm Development	2001-01-01	2008-01-01	1828d																																

Handwritten note: } 7 mo 38MPT 5 1/2 FTE

Milestones: **bold type**
Summary Tasks: underline

Task Milestone

Summary

APPENDIX B

COST TABLES

Millimeter Array Construction: Project Totals

WBS	Name	Scientists Work-Months	Programmers Work-Months	Engineers Work-Months	Technicians Work-Months	Personnel Cost	Materials and Supplies	Transfer to Operations	Adjustment to Scope	Contingency	Sum Cost	Inflated Contingency	Inflated Sum
1	Administration	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
1.1	Project Management	504	0	0	288	\$ 5,499	\$ -	\$ 1,170	\$ -	\$ 649	\$ 4,329	\$ 699	\$ 4,660
1.1.1	Management, Planning, and Oversight	0	0	0	0	\$ -	\$ 4,500	\$ -	\$ -	\$ 495	\$ 4,500	\$ 545	\$ 4,876
1.1.2	Business Operations	0	0	0	0	\$ -	\$ 580	\$ -	\$ -	\$ 87	\$ 580	\$ 95	\$ 633
1.1.3	Chilean Operations	0	0	0	0	\$ -	\$ 350	\$ -	\$ -	\$ 53	\$ 350	\$ 57	\$ 377
1.1.4	Safety and Health	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
1.1.5	Personnel	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
1.1.6	Project Science Office	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
1.1.7	AUI Management	0	0	0	0	\$ -	\$ 2,450	\$ -	\$ -	\$ -	\$ 2,450	\$ -	\$ 2,642
1.2	Engineering	0	0	168	84	\$ 2,048	\$ 140	\$ -	\$ -	\$ 328	\$ 2,188	\$ 354	\$ 2,359
1.2.1	System Engineering--Phase II	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
1.2.2	Documentation System	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
1.2.3	Production Engineering	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
1.3	US Facilities	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
1.3.1	CDL Permanent Facilities	0	0	0	0	\$ -	\$ 3,000	\$ -	\$ -	\$ -	\$ 3,000	\$ -	\$ 3,154
1.3.2	Manufacturing Facilities	0	0	0	0	\$ -	\$ 700	\$ -	\$ -	\$ 105	\$ 700	\$ 113	\$ 755
1.3.3	Common Infrastructure	0	0	0	0	\$ -	\$ 1,400	\$ -	\$ -	\$ 210	\$ 1,400	\$ 226	\$ 1,509
		0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
2	Site Development	0	0	84	0	\$ 819	\$ 350	\$ -	\$ -	\$ 183	\$ 1,169	\$ 197	\$ 1,260
2.1	Review Legalities Regarding Array and OSF Sites	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
2.2	Maintain Mining claims	0	0	0	0	\$ -	\$ 150	\$ -	\$ -	\$ -	\$ 150	\$ -	\$ 160
2.3	Contract A&E Studies	0	0	0	0	\$ -	\$ 938	\$ -	\$ 104	\$ 167	\$ 834	\$ 167	\$ 834
2.4	Hire Construction Manager for Chile	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
2.5	Array Site	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
2.5.1	Prepare Site Development Bid Packages	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
2.5.1.1	Prepare Package for Array Site	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
2.5.1.2	Review Bid Packages	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
2.5.1.3	Bid Civil Works Construction	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
2.5.2	Evaluate Array Site Bid Response	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
2.5.2.1	Review Bids	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
2.5.2.2	Recommend Contractors	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
2.5.2.3	Award Array Site Contracts	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
2.5.3	Contract Array Site Civil Works	0	0	0	0	\$ -	\$ 23,343	\$ -	\$ 2,870	\$ 4,095	\$ 20,473	\$ 4,223	\$ 21,116
2.5.3.1	Array Site	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
2.5.3.2	Inspect Completed Site Constr	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
2.5.3.3	Accept Site Facility	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
2.6	Operations Support Facility	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
2.6.1	Prepare OSF Bid Packages	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
2.6.1.1	Prepare Package for OSF	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
2.6.1.2	Review Bid Packages	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
2.6.1.3	Bid Civil Works Construction	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
2.6.2	Evaluate OSF Bid Response	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
2.6.2.1	Review Bids	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
2.6.2.2	Recommend Contractors	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
2.6.2.3	Award Contracts	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -

2.6.3	Contract OSF Civil Works	0	0	0	0	\$ -	\$ 14,183	\$ 717	\$ 811	\$ 2,567	\$ 12,655	\$ 2,648	\$ 13,052
2.6.3.1	Operations Support Facility	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
2.6.3.2	Inspect Completed OSF Constr	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
2.6.3.3	Accept OSF Facility	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
2.7	OSF/Array Link	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
2.7.1	Prepare OSF/Array Link Bid Package	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
2.7.1.1	Prepare Package for OSF/Array F/O Link	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
2.7.1.2	Review Bid Package	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
2.7.1.3	Bid OSF/Array Link Construction	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
2.7.2	Evaluate Bid Response	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
2.7.2.1	Review Bids	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
2.7.2.2	Recommend Contractors	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
2.7.2.3	Award Contracts	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
2.7.3	Contract Civil Works	0	0	0	0	\$ -	\$ 3,890	\$ -	\$ -	\$ 778	\$ 3,890	\$ 797	\$ 3,987
2.7.3.1	OSF/Array Link	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
2.7.3.2	Inspect Completed OSF/Array Link Constr	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
2.7.3.3	Accept OSF/Array Link	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
2.8	Prepare for Instrument Assembly	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
2.8.1	Equip Array Site	0	0	0	0	\$ -	\$ 8,030	\$ 2,200	\$ -	\$ 1,276	\$ 5,830	\$ 1,318	\$ 5,997
2.8.2	Equip Operations Support Facility	0	0	0	0	\$ -	\$ 3,450	\$ 1,250	\$ -	\$ 503	\$ 2,200	\$ 541	\$ 2,369
		0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
		0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
3	Antenna	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
3.1	Antenna Engineering Support	0	0	96	0	\$ 936	\$ -	\$ -	\$ -	\$ 140	\$ 936	\$ 142	\$ 948
3.3.40	Acceptance Tests Antenna #1	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
3.3.45	Delivery of Antenna #1	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
3.8.10	Sign Transporter Contract	0	0	0	0	\$ -	\$ 600	\$ -	\$ -	\$ 180	\$ 600	\$ 180	\$ 600
3.8.15	Transporter Acceptance tests	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
3.8.20	Deliver/Accept Transporter #1	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
3.7	Procurement of Antenna #2	0	0	0	0	\$ -	\$ 2,050	\$ -	\$ -	\$ 615	\$ 2,050	\$ 662	\$ 2,208
3.7.1	Antenna #2 Contract Supervision	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
3.7.2	Antenna #2 Acceptance tests	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
3.8	Negotiate Production Antenna Contract	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
3.9	Sign Contract for Production Antennas	0	0	0	0	\$ -	\$ 1,000	\$ -	\$ -	\$ 200	\$ 1,000	\$ 210	\$ 1,051
3.10	Antenna Contract Supervision	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
3.11	Accept Antenna #3 at OSF	0	0	4.5	0	\$ 44	\$ 2,832	\$ -	\$ -	\$ 573	\$ 2,876	\$ 602	\$ 3,022
3.12	Prepare Antenna #3	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
3.12.1	Outfit & Verify Ant #3 at OSF	0	0	2	4	\$ 39	\$ -	\$ -	\$ -	\$ 6	\$ 39	\$ 6	\$ 42
3.12.2	Move, Install & Verify Ant #3 on Site	0	0	1	1	\$ 15	\$ -	\$ -	\$ -	\$ 2	\$ 15	\$ 2	\$ 16
3.13	Accept Antenna #4 at OSF	0	0	4.5	0	\$ 44	\$ 2,832	\$ -	\$ -	\$ 573	\$ 2,876	\$ 602	\$ 3,022
3.14	Prepare Antenna #4	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
3.14.1	Outfit & Verify Ant #4 at OSF	0	0	2	4	\$ 39	\$ -	\$ -	\$ -	\$ 6	\$ 39	\$ 6	\$ 42
3.14.2	Move, Install & Verify Ant #4 on Site	0	0	1	1	\$ 15	\$ -	\$ -	\$ -	\$ 2	\$ 15	\$ 2	\$ 16
3.15	Accept Antenna#5 at OSF	0	0	4.5	0	\$ 44	\$ 2,832	\$ -	\$ -	\$ 573	\$ 2,876	\$ 602	\$ 3,022
3.16	Prepare Antenna #5	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
3.16.1	Outfit & Verify Ant #5 at OSF	0	0	2	4	\$ 39	\$ -	\$ -	\$ -	\$ 6	\$ 39	\$ 6	\$ 42
3.16.2	Move, Install & Verify Ant #5 on Site	0	0	1	1	\$ 15	\$ -	\$ -	\$ -	\$ 2	\$ 15	\$ 2	\$ 16
3.17	Accept Antenna#6 at OSF	0	0	4.5	0	\$ 44	\$ 2,832	\$ -	\$ -	\$ 573	\$ 2,876	\$ 602	\$ 3,022
3.18	Prepare Antenna #6	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
3.18.1	Outfit & Verify Ant #6 at OSF	0	0	2	4	\$ 39	\$ -	\$ -	\$ -	\$ 6	\$ 39	\$ 6	\$ 42
3.18.2	Move, Install & Verify Ant #6 on Site	0	0	1	1	\$ 15	\$ -	\$ -	\$ -	\$ 2	\$ 15	\$ 2	\$ 16

Millimeter Array
Construction:
Project Totals

3.19	Accept Antenna #7 at OSF	0	0	4.5	0	\$ 44	\$ 2,832	\$ -	\$ -	\$ 856	\$ 2,876	\$ 922	\$ 3,097
3.20	Prepare Antenna #7	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
3.20.1	Outfit & Verify Ant #7 at OSF	0	0	2	4	\$ 39	\$ -	\$ -	\$ -	\$ 6	\$ 39	\$ 6	\$ 43
3.20.2	Move, Install & Verify Ant #7 on Site	0	0	1	1	\$ 15	\$ -	\$ -	\$ -	\$ 2	\$ 15	\$ 2	\$ 16
3.21	Accept Antenna #8 at OSF	0	0	4.5	0	\$ 44	\$ 2,832	\$ -	\$ -	\$ 856	\$ 2,876	\$ 922	\$ 3,097
3.22	Prepare Antenna #8	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
3.22.1	Outfit & Verify Ant #8 at OSF	0	0	2	4	\$ 39	\$ -	\$ -	\$ -	\$ 6	\$ 39	\$ 6	\$ 43
3.22.2	Move, Install & Verify Ant #8 on Site	0	0	1	1	\$ 15	\$ -	\$ -	\$ -	\$ 2	\$ 15	\$ 2	\$ 16
3.23	Accept Antenna #9 at OSF	0	0	4.5	0	\$ 44	\$ 2,832	\$ -	\$ -	\$ 856	\$ 2,876	\$ 922	\$ 3,097
3.24	Prepare Antenna #9	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
3.24.1	Outfit & Verify Ant #9 at OSF	0	0	2	4	\$ 39	\$ -	\$ -	\$ -	\$ 6	\$ 39	\$ 6	\$ 43
3.24.2	Move, Install & Verify Ant #9 on Site	0	0	1	1	\$ 15	\$ -	\$ -	\$ -	\$ 2	\$ 15	\$ 2	\$ 16
3.25	Accept Antenna #10 at OSF	0	0	4.5	0	\$ 44	\$ 2,832	\$ -	\$ -	\$ 856	\$ 2,876	\$ 922	\$ 3,097
3.26	Prepare Antenna #10	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
3.26.1	Outfit & Verify Ant #10 at OSF	0	0	2	4	\$ 39	\$ -	\$ -	\$ -	\$ 6	\$ 39	\$ 6	\$ 43
3.26.2	Move, Install and Verify Ant #10 on Site	0	0	1	1	\$ 15	\$ -	\$ -	\$ -	\$ 2	\$ 15	\$ 2	\$ 16
3.27	Accept Antenna #11 at OSF	0	0	4.5	0	\$ 44	\$ 2,832	\$ -	\$ -	\$ 856	\$ 2,876	\$ 922	\$ 3,097
3.28	Prepare Antenna #11	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
3.28.1	Outfit & Verify Ant #11 at OSF	0	0	2	4	\$ 39	\$ -	\$ -	\$ -	\$ 6	\$ 39	\$ 6	\$ 43
3.28.2	Move, Install & Verify Ant #11 on Site	0	0	1	1	\$ 15	\$ -	\$ -	\$ -	\$ 2	\$ 15	\$ 2	\$ 16
3.29	Accept Antenna #12 at OSF	0	0	4.5	0	\$ 44	\$ 2,832	\$ -	\$ -	\$ 856	\$ 2,876	\$ 922	\$ 3,097
3.30	Prepare Antenna #12	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
3.30.1	Outfit & Verify Ant #12 at OSF	0	0	2	4	\$ 39	\$ -	\$ -	\$ -	\$ 6	\$ 39	\$ 6	\$ 43
3.30.2	Move, Install & Verify Ant #12 on Site	0	0	1	1	\$ 15	\$ -	\$ -	\$ -	\$ 2	\$ 15	\$ 2	\$ 16
3.31	Accept Antenna #13 at OSF	0	0	4.5	0	\$ 44	\$ 2,832	\$ -	\$ -	\$ 856	\$ 2,876	\$ 922	\$ 3,097
3.32	Prepare Antenna #13	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
3.32.1	Outfit & Verify Ant #13 at OSF	0	0	2	4	\$ 39	\$ -	\$ -	\$ -	\$ 6	\$ 39	\$ 6	\$ 43
3.32.2	Move, Install & Verify Ant #13 on Site	0	0	1	1	\$ 15	\$ -	\$ -	\$ -	\$ 2	\$ 15	\$ 2	\$ 16
3.33	Accept Antenna #14 at OSF	0	0	4.5	0	\$ 44	\$ 2,832	\$ -	\$ -	\$ 856	\$ 2,876	\$ 922	\$ 3,097
3.34	Prepare Antenna #14	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
3.34.1	Outfit & Verify Ant #14 at OSF	0	0	2	4	\$ 39	\$ -	\$ -	\$ -	\$ 6	\$ 39	\$ 6	\$ 43
3.34.2	Move, Install & Verify Ant #14 on Site	0	0	1	1	\$ 15	\$ -	\$ -	\$ -	\$ 2	\$ 15	\$ 2	\$ 16
3.35	Accept Antenna #15 at OSF	0	0	4.5	0	\$ 44	\$ 2,832	\$ -	\$ -	\$ 856	\$ 2,876	\$ 922	\$ 3,097
3.36	Prepare Antenna #15	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
3.36.1	Outfit & Verify Ant #15 at OSF	0	0	2	4	\$ 39	\$ -	\$ -	\$ -	\$ 6	\$ 39	\$ 6	\$ 43
3.36.2	Move, Install & Verify Ant #15 on Site	0	0	1	1	\$ 15	\$ -	\$ -	\$ -	\$ 2	\$ 15	\$ 2	\$ 16
3.37	Accept Antenna #16 at OSF	0	0	4.5	0	\$ 44	\$ 2,832	\$ -	\$ -	\$ 856	\$ 2,876	\$ 945	\$ 3,175
3.38	Prepare Antenna #16	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
3.38.1	Outfit & Verify Ant #16 at OSF	0	0	2	4	\$ 39	\$ -	\$ -	\$ -	\$ 6	\$ 39	\$ 7	\$ 44
3.38.2	Move, Install & Verify Ant #16 on Site	0	0	1	1	\$ 15	\$ -	\$ -	\$ -	\$ 2	\$ 15	\$ 2	\$ 17
3.39	Accept Antenna #17 at OSF	0	0	4.5	0	\$ 44	\$ 2,832	\$ -	\$ -	\$ 856	\$ 2,876	\$ 945	\$ 3,175
3.40	Prepare Antenna #17	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
3.40.1	Outfit & Verify Ant #17 at OSF	0	0	2	4	\$ 39	\$ -	\$ -	\$ -	\$ 6	\$ 39	\$ 7	\$ 44
3.40.2	Move, Install & Verify Ant #17 on Site	0	0	1	1	\$ 15	\$ -	\$ -	\$ -	\$ 2	\$ 15	\$ 2	\$ 17
3.41	Accept Antenna #18 at OSF	0	0	4.5	0	\$ 44	\$ 2,832	\$ -	\$ -	\$ 856	\$ 2,876	\$ 945	\$ 3,175
3.42	Prepare Antenna #18	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
3.42.1	Outfit & Verify Ant #18 at OSF	0	0	2	4	\$ 39	\$ -	\$ -	\$ -	\$ 6	\$ 39	\$ 7	\$ 44
3.42.2	Move, Install & Verify Ant #18 on Site	0	0	1	1	\$ 15	\$ -	\$ -	\$ -	\$ 2	\$ 15	\$ 2	\$ 17
3.43	Accept Antenna #19 at OSF	0	0	4.5	0	\$ 44	\$ 2,832	\$ -	\$ -	\$ 856	\$ 2,876	\$ 945	\$ 3,175
3.44	Prepare Antenna #19	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
3.44.1	Outfit & Verify Ant #19 at OSF	0	0	2	4	\$ 39	\$ -	\$ -	\$ -	\$ 6	\$ 39	\$ 7	\$ 44
3.44.2	Move, Install & Verify Ant #19 on Site	0	0	1	1	\$ 15	\$ -	\$ -	\$ -	\$ 2	\$ 15	\$ 2	\$ 17
3.45	Accept Antenna #20 at OSF	0	0	4.5	0	\$ 44	\$ 2,832	\$ -	\$ -	\$ 856	\$ 2,876	\$ 945	\$ 3,175

Millimeter Array
Construction:
Project Totals

3.46	Prepare Antenna #20	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
3.46.1	Outfit & Verify Ant #20 at OSF	0	0	2	4	\$ 39	\$ -	\$ -	\$ -	\$ -	\$ 6	\$ 39	\$ 7	\$ 44
3.46.2	Move, Install & Verify Ant #20 on Site	0	0	1	1	\$ 15	\$ -	\$ -	\$ -	\$ -	\$ 2	\$ 15	\$ 2	\$ 17
3.47	Accept Antenna #21 at OSF	0	0	4.5	0	\$ 44	\$ 2,832	\$ -	\$ -	\$ -	\$ 856	\$ 2,876	\$ 945	\$ 3,175
3.48	Prepare Antenna #21	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
3.48.1	Outfit & Verify Ant #21 at OSF	0	0	2	4	\$ 39	\$ -	\$ -	\$ -	\$ -	\$ 6	\$ 39	\$ 7	\$ 44
3.48.2	Move, Install & Verify Ant #21 on Site	0	0	1	1	\$ 15	\$ -	\$ -	\$ -	\$ -	\$ 2	\$ 15	\$ 2	\$ 17
3.49	Accept Antenna #22 at OSF	0	0	4.5	0	\$ 44	\$ 2,832	\$ -	\$ -	\$ -	\$ 856	\$ 2,876	\$ 945	\$ 3,175
3.50	Prepare Antenna #22	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
3.50.1	Outfit & Verify Ant #22 at OSF	0	0	2	4	\$ 39	\$ -	\$ -	\$ -	\$ -	\$ 6	\$ 39	\$ 7	\$ 44
3.50.2	Move, Install & Verify Ant #22 on Site	0	0	1	1	\$ 15	\$ -	\$ -	\$ -	\$ -	\$ 2	\$ 15	\$ 2	\$ 17
3.51	Accept Antenna #23 at OSF	0	0	4.5	0	\$ 44	\$ 2,832	\$ -	\$ -	\$ -	\$ 856	\$ 2,876	\$ 945	\$ 3,175
3.52	Prepare Antenna #23	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
3.52.1	Outfit & Verify Ant #23 at OSF	0	0	2	4	\$ 39	\$ -	\$ -	\$ -	\$ -	\$ 6	\$ 39	\$ 7	\$ 44
3.52.2	Move, Install & Verify Ant #23 on Site	0	0	1	1	\$ 15	\$ -	\$ -	\$ -	\$ -	\$ 2	\$ 15	\$ 2	\$ 17
3.53	Accept Antenna #24 at OSF	0	0	4.5	0	\$ 44	\$ 2,832	\$ -	\$ -	\$ -	\$ 856	\$ 2,876	\$ 945	\$ 3,175
3.54	Prepare Antenna #24	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
3.54.1	Outfit & Verify Ant #24 at OSF	0	0	2	4	\$ 39	\$ -	\$ -	\$ -	\$ -	\$ 6	\$ 39	\$ 7	\$ 44
3.54.2	Move, Install & Verify Ant #24 on Site	0	0	1	1	\$ 15	\$ -	\$ -	\$ -	\$ -	\$ 2	\$ 15	\$ 2	\$ 17
3.55	Accept Antenna #25 at OSF	0	0	4.5	0	\$ 44	\$ 2,832	\$ -	\$ -	\$ -	\$ 856	\$ 2,876	\$ 945	\$ 3,175
3.56	Prepare Antenna #25	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
3.56.1	Outfit & Verify Ant #25 at OSF	0	0	2	4	\$ 39	\$ -	\$ -	\$ -	\$ -	\$ 6	\$ 39	\$ 7	\$ 44
3.56.2	Move, Install & Verify Ant #25 on Site	0	0	1	1	\$ 15	\$ -	\$ -	\$ -	\$ -	\$ 2	\$ 15	\$ 2	\$ 17
3.57	Accept Antenna #26 at OSF	0	0	4.5	0	\$ 44	\$ 2,832	\$ -	\$ -	\$ -	\$ 856	\$ 2,876	\$ 945	\$ 3,175
3.58	Prepare Antenna #26	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
3.58.1	Outfit & Verify Ant #26 at OSF	0	0	2	4	\$ 39	\$ -	\$ -	\$ -	\$ -	\$ 6	\$ 39	\$ 7	\$ 44
3.58.2	Move, Install & Verify Ant #26 on Site	0	0	1	1	\$ 15	\$ -	\$ -	\$ -	\$ -	\$ 2	\$ 15	\$ 2	\$ 17
3.59	Accept Antenna #27 at OSF	0	0	4.5	0	\$ 44	\$ 2,832	\$ -	\$ -	\$ -	\$ 856	\$ 2,876	\$ 945	\$ 3,175
3.60	Prepare Antenna #27	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
3.60.1	Outfit & Verify Ant #27 at OSF	0	0	2	4	\$ 39	\$ -	\$ -	\$ -	\$ -	\$ 6	\$ 39	\$ 7	\$ 44
3.60.2	Move, Install & Verify Ant #27 on Site	0	0	1	1	\$ 15	\$ -	\$ -	\$ -	\$ -	\$ 2	\$ 15	\$ 2	\$ 17
3.61	Accept Antenna #28 at OSF	0	0	4.5	0	\$ 44	\$ 2,832	\$ -	\$ -	\$ -	\$ 856	\$ 2,876	\$ 969	\$ 3,254
3.62	Prepare Antenna #28	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
3.62.1	Outfit & Verify Ant #28 at OSF	0	0	2	4	\$ 39	\$ -	\$ -	\$ -	\$ -	\$ 6	\$ 39	\$ 7	\$ 45
3.62.2	Move, Install & Verify Ant #28 on Site	0	0	1	1	\$ 15	\$ -	\$ -	\$ -	\$ -	\$ 2	\$ 15	\$ 3	\$ 17
3.63	Accept Antenna #29 at OSF	0	0	4.5	0	\$ 44	\$ 2,832	\$ -	\$ -	\$ -	\$ 856	\$ 2,876	\$ 969	\$ 3,254
3.64	Prepare Antenna #29	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
3.64.1	Outfit & Verify Ant #29 at OSF	0	0	2	4	\$ 39	\$ -	\$ -	\$ -	\$ -	\$ 6	\$ 39	\$ 7	\$ 45
3.64.2	Move, Install & Verify Ant #29 on Site	0	0	1	1	\$ 15	\$ -	\$ -	\$ -	\$ -	\$ 2	\$ 15	\$ 3	\$ 17
3.65	Accept Antenna #30 at OSF	0	0	4.5	0	\$ 44	\$ 2,832	\$ -	\$ -	\$ -	\$ 856	\$ 2,876	\$ 969	\$ 3,254
3.66	Prepare Antenna #30	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
3.66.1	Outfit & Verify Ant #30 at OSF	0	0	2	4	\$ 39	\$ -	\$ -	\$ -	\$ -	\$ 6	\$ 39	\$ 7	\$ 45
3.66.2	Move, Install & Verify Ant #30 on Site	0	0	1	1	\$ 15	\$ -	\$ -	\$ -	\$ -	\$ 2	\$ 15	\$ 3	\$ 17
3.67	Accept Antenna #31 at OSF	0	0	4.5	0	\$ 44	\$ 2,832	\$ -	\$ -	\$ -	\$ 856	\$ 2,876	\$ 969	\$ 3,254
3.68	Prepare Antenna #31	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
3.68.1	Outfit & Verify Ant #31 at OSF	0	0	2	4	\$ 39	\$ -	\$ -	\$ -	\$ -	\$ 6	\$ 39	\$ 7	\$ 45
3.68.2	Move, Install and Verify Ant #31 on Site	0	0	1	1	\$ 15	\$ -	\$ -	\$ -	\$ -	\$ 2	\$ 15	\$ 3	\$ 17
3.69	Accept Antenna #32 at OSF	0	0	4.5	0	\$ 44	\$ 2,832	\$ -	\$ -	\$ -	\$ 856	\$ 2,876	\$ 969	\$ 3,254
3.70	Prepare Antenna #32	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
3.70.1	Outfit & Verify Ant #32 at OSF	0	0	2	4	\$ 39	\$ -	\$ -	\$ -	\$ -	\$ 6	\$ 39	\$ 7	\$ 45
3.70.2	Move, Install & Verify Ant #32 on Site	0	0	1	1	\$ 15	\$ -	\$ -	\$ -	\$ -	\$ 2	\$ 15	\$ 3	\$ 17
3.71	Accept Antenna #33 at OSF	0	0	4.5	0	\$ 44	\$ 2,832	\$ -	\$ -	\$ 2,861	\$ 856	\$ 2,876	\$ 969	\$ 3,254
3.72	Prepare Antenna #33	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -

Millimeter Array
Construction:
Project Totals

3.72.1	Outfit & Verify Ant #33 at OSF	0	0	2	4	\$	39	\$	-	\$	-	\$	39	\$	-	\$	-	\$	-	\$	-	\$	-
3.72.2	Move, Install and Verify Ant #33 on Site	0	0	1	1	\$	15	\$	-	\$	-	\$	15	\$	-	\$	-	\$	-	\$	-	\$	-
3.73	Accept Antenna #34 at OSF	0	0	4.5	0	\$	44	\$	2,832	\$	-	\$	2,876	\$	-	\$	-	\$	-	\$	-	\$	-
3.74	Prepare Antenna #34	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
3.74.1	Outfit & Verify Ant #34 at OSF	0	0	2	4	\$	39	\$	-	\$	-	\$	39	\$	-	\$	-	\$	-	\$	-	\$	-
3.74.2	Move, Install and Verify Ant #34 on Site	0	0	1	1	\$	15	\$	-	\$	-	\$	15	\$	-	\$	-	\$	-	\$	-	\$	-
3.75	Accept Antenna #35 at OSF	0	0	4.5	0	\$	44	\$	2,832	\$	-	\$	2,876	\$	-	\$	-	\$	-	\$	-	\$	-
3.76	Prepare Antenna #35	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
3.76.1	Outfit & Verify Ant #35 at OSF	0	0	2	4	\$	39	\$	-	\$	-	\$	39	\$	-	\$	-	\$	-	\$	-	\$	-
3.76.2	Move, Install & Verify Ant #35 on Site	0	0	1	1	\$	15	\$	-	\$	-	\$	15	\$	-	\$	-	\$	-	\$	-	\$	-
3.77	Accept Antenna #36 at OSF	0	0	4.5	0	\$	44	\$	2,832	\$	-	\$	2,876	\$	-	\$	-	\$	-	\$	-	\$	-
3.78	Prepare Antenna #36	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
3.78.1	Outfit & Verify Ant #36 at OSF	0	0	2	4	\$	39	\$	-	\$	-	\$	39	\$	-	\$	-	\$	-	\$	-	\$	-
3.78.2	Move, Install & Verify Ant #36 on Site	0	0	1	1	\$	15	\$	-	\$	-	\$	15	\$	-	\$	-	\$	-	\$	-	\$	-
3.79	Prepare Antenna #1	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
3.79.1	Antenna #1 Reassembled at OSF	0	0	1.5	0	\$	15	\$	388	\$	-	\$	-	\$	119	\$	403	\$	-	\$	131	\$	445
3.79.2	Outfit & Verify Ant #1 at OSF	0	0	2	4	\$	39	\$	-	\$	-	\$	-	\$	6	\$	39	\$	-	\$	7	\$	45
3.79.3	Move, Install & Verify Ant #1 on Site	0	0	1	1	\$	15	\$	-	\$	-	\$	-	\$	2	\$	15	\$	-	\$	3	\$	17
3.80	Prepare Antenna #2	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
3.80.1	Antenna #2 Reassembled at OSF	0	0	1.5	0	\$	15	\$	388	\$	-	\$	-	\$	119	\$	403	\$	-	\$	131	\$	445
3.80.2	Outfit & Verify Ant #2 at OSF	0	0	2	4	\$	39	\$	-	\$	-	\$	-	\$	6	\$	39	\$	-	\$	7	\$	45
3.80.3	Move, Install & Verify Ant #2 on Site	0	0	1	1	\$	15	\$	-	\$	-	\$	-	\$	2	\$	15	\$	-	\$	3	\$	17
3.81	Antenna Transporter	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
3.81.1	Contract for Transporter #1, move to Site	0	0	0	0	\$	-	\$	120	\$	-	\$	-	\$	36	\$	120	\$	-	\$	39	\$	131
3.81.2	Contract for Transporters #2, #3	0	0	0	0	\$	-	\$	1,508	\$	-	\$	754	\$	151	\$	754	\$	-	\$	158	\$	792
3.81.3	Accept Transporters #2, #3 at OSF	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
4	Receivers	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
4.1	Receiver Package	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
4.1.1	Prototype Production Receiver Cryogenics	0	0	12	12	\$	176	\$	100	\$	-	\$	-	\$	41	\$	276	\$	-	\$	41	\$	276
4.1.1.1	CDR: Cryogenics Development	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
4.1.1.2	Construct & test prototype cryogenics	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
4.1.1.3	Deliver Prototype Cryogenics Subsystem	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
4.1.2	Prototype Production Receiver Package	0	0	36	36	\$	527	\$	250	\$	-	\$	-	\$	131	\$	777	\$	-	\$	133	\$	783
4.1.2.1	Prototype Receiver Package Integration	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
4.1.2.2	Prot. Rcvr. Pckg Lab Test & Evaluation	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
4.1.2.3	Complete Prototype MMA Receiver Package	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
4.1.3	MMA Rcvr Pckg Design Refinement	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
4.1.4	Documentation	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
4.1.5	Release MMA Receiver Pckg for manufacture	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
4.1.6	Contract for Receiver Pckg Subassemblies	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
4.1.6.1	Machine Dewars	0	0	0	180	\$	878	\$	300	\$	-	\$	131	\$	180	\$	1,047	\$	-	\$	196	\$	1,142
4.1.6.2	Fabricate Cryogenics subsystems	0	0	36	144	\$	1,053	\$	1,440	\$	-	\$	277	\$	487	\$	2,216	\$	-	\$	533	\$	2,418
4.1.6.3	Fabricate windows, IR filters, etc	0	0	36	180	\$	1,229	\$	600	\$	-	\$	203	\$	297	\$	1,625	\$	-	\$	324	\$	1,774
4.1.7	Accept Receiver Pckg Subassemblies	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
4.1.7.1	Subassemblies #1-6	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
4.1.7.2	Subassemblies #7-16	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
4.1.7.3	Subassemblies #17-26	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
4.1.7.4	Subassemblies #27-36	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
4.1.7.5	Subassemblies #37-40	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-

Millimeter Array
Construction:
Project Totals

4.1.8	Fab Rcvr Pckg Instrumentation & Electronics	0	30	33	72	\$ 933	\$ 550	\$ -	\$ 165	\$ 249	\$ 1,318	\$ 269	\$ 1,419
4.1.9	Fabricate Receiver Inserts	0	0	120	168	\$ 1,989	\$ 600	\$ -	\$ 288	\$ 387	\$ 2,301	\$ 422	\$ 2,509
4.1.10	Assemble Receiver Package	0	0	24	36	\$ 410	\$ 80	\$ -	\$ 54	\$ 67	\$ 435	\$ 70	\$ 457
4.1.10.1	Integrate Rcvr Instrumentation & subass'y	0	0	72	228	\$ 1,814	\$ 400	\$ -	\$ 246	\$ 318	\$ 1,968	\$ 349	\$ 2,159
4.1.10.2	Deliver Receiver Package #1-6	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.1.10.3	Deliver Receiver Package #7-16	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.1.10.4	Deliver Receiver Package #17-26	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.1.10.5	Deliver Receiver Package #27-36	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.1.10.6	Deliver Receiver Package #37-40	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.2	SIS Receiver Modules	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.2.1	211-275 GHz Module	0	0	60	48	\$ 819	\$ 500	\$ -	\$ 147	\$ 229	\$ 1,172	\$ 231	\$ 1,185
4.2.1.1	SIS Mixer	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.2.1.1.1	Design, Fab and Test Mixer Design	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.2.1.1.2	Deliver Production Design	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.2.1.1.3	Fabricate Production Mixers	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.2.1.2	Design & Verify Optics	0	0	6	0	\$ 59	\$ 50	\$ -	\$ -	\$ 24	\$ 109	\$ 24	\$ 109
4.2.1.3	Design Module	0	0	6	0	\$ 59	\$ 50	\$ -	\$ -	\$ 24	\$ 109	\$ 24	\$ 109
4.2.1.4	Contract Fabrication	0	0	0	16	\$ 78	\$ 250	\$ -	\$ 32	\$ 69	\$ 297	\$ 71	\$ 308
4.2.1.4.1	Machine Mixer Blocks, Feed, WG, Lenses	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.2.1.4.2	Assemble Modules	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.2.1.5	Install SIS Mixer & Test Modules	0	0	48	96	\$ 936	\$ 100	\$ -	\$ 115	\$ 137	\$ 921	\$ 144	\$ 970
4.2.1.6	Deliver 211-275 GHz Receiver Modules	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.2.1.6.1	Deliver Modules #1-7	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.2.1.6.2	Deliver Modules #8-26	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.2.1.6.3	Deliver Modules #27-40	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.2.2	602-720 GHz Module	0	0	60	48	\$ 819	\$ 500	\$ -	\$ 1,319	\$ -	\$ -	\$ -	\$ -
4.2.2.1	SIS Mixer	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.2.2.1.1	Design, Fabricate and Test Mixer Design	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.2.2.1.2	Deliver Production Design	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.2.2.1.3	Fabricate Production Mixers	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.2.2.2	Design & Verify Optics	0	0	6	0	\$ 59	\$ 50	\$ -	\$ 109	\$ -	\$ -	\$ -	\$ -
4.2.2.3	Design Module	0	0	6	0	\$ 59	\$ 50	\$ -	\$ 109	\$ -	\$ -	\$ -	\$ -
4.2.2.4	Contract Fabrication	0	0	0	16	\$ 78	\$ 250	\$ -	\$ 328	\$ -	\$ -	\$ -	\$ -
4.2.2.4.1	Machine Mixer Blocks, Feed, WG, Lenses	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.2.2.4.2	Assemble Modules	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.2.2.5	Install SIS Mixer and Test Modules	0	0	48	96	\$ 936	\$ 100	\$ -	\$ 1,036	\$ -	\$ -	\$ -	\$ -
4.2.2.6	Deliver 602-720 GHz Receiver Modules	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.2.2.6.1	Deliver Modules #1-7	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.2.2.6.2	Deliver Modules #8-26	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.2.2.6.3	Deliver Modules #27-40	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.2.3	275-370 GHz Receiver Module	0	0	60	48	\$ 819	\$ 500	\$ -	\$ 147	\$ 225	\$ 1,172	\$ 233	\$ 1,215
4.2.3.1	SIS Mixer	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.2.3.1.1	Design, Fabricate and Test Mixer Design	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.2.3.1.2	Deliver Production Design	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.2.3.1.3	Fabricate Production Mixers	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.2.3.2	Design & Verify Optics	0	0	6	0	\$ 59	\$ 50	\$ -	\$ 2	\$ 23	\$ 106	\$ 23	\$ 107
4.2.3.3	Design Module	0	0	6	0	\$ 59	\$ 50	\$ -	\$ 12	\$ 20	\$ 96	\$ 21	\$ 99
4.2.3.4	Contract Fabrication	0	0	0	10	\$ 49	\$ 250	\$ -	\$ 31	\$ 64	\$ 268	\$ 68	\$ 283
4.2.3.4.1	Machine Mixer Blocks, Feed, WG, Lenses	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.2.3.4.2	Assemble Modules	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -

Millimeter Array
Construction:
Project Totals

4.2.3.5	Install SIS Mixer and Test Modules	0	0	48	96	\$ 936	\$ 120	\$ -	\$ 78	\$ 152	\$ 978	\$ 164	\$ 1,056
4.2.3.6	Deliver 275-370 GHz Receiver Module	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.2.3.6.1	Deliver Modules #1-5	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.2.3.6.2	Deliver Modules #6-30	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.2.3.6.3	Deliver Modules #30-40	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.2.4	91-119 GHz Receiver Module	0	0	60	48	\$ 819	\$ 500	\$ -	\$ 147	\$ 225	\$ 1,172	\$ 233	\$ #REF!
4.2.4.1	SIS Mixer	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.2.4.1.1	Design, Fabricate & Test Mixer Design	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 329
4.2.4.1.2	Deliver Production Design	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.2.4.1.3	Fabricate Production Mixers	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.2.4.2	Design & Verify Optics	0	0	6	0	\$ 59	\$ 50	\$ -	\$ 2	\$ 23	\$ 106	\$ 23	\$ 107
4.2.4.3	Design Module	0	0	6	0	\$ 59	\$ 50	\$ -	\$ 12	\$ 20	\$ 96	\$ 21	\$ 99
4.2.4.4	Contract Fabrication	0	0	0	10	\$ 49	\$ 250	\$ -	\$ 31	\$ 64	\$ 268	\$ 68	\$ 283
4.2.4.4.1	Machine Mixer Blocks, Feed, WG, Lenses	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.2.4.4.2	Assemble Modules	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.2.4.5	Install SIS Mixer and Test Modules	0	0	48	96	\$ 936	\$ 120	\$ -	\$ 78	\$ 152	\$ 978	\$ 164	\$ 1,056
4.2.4.6	Deliver 91-119 GHz Receiver Modules	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.2.4.6.1	Deliver Modules #1-5	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.2.4.6.2	Deliver Modules #6-30	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.2.4.6.3	Deliver Modules # 31-40	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.2.5	163-211 GHz Receiver Module	0	0	60	48	\$ 819	\$ 500	\$ -	\$ 95	\$ 213	\$ 1,224	\$ 226	\$ 1,301
4.2.5.1	SIS Mixer	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.2.5.1.1	Design, Fabricate & Test Mixer Design	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.2.5.1.2	Deliver Production Design	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.2.5.1.3	Fabricate Production Mixers	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.2.5.2	Design & Verify Optics	0	0	6	0	\$ 59	\$ 50	\$ -	\$ 12	\$ 20	\$ 96	\$ 21	\$ 99
4.2.5.3	Design Module	0	0	6	0	\$ 59	\$ 50	\$ -	\$ 12	\$ 20	\$ 96	\$ 21	\$ 99
4.2.5.4	Contract Fabrication	0	0	0	10	\$ 49	\$ 250	\$ -	\$ 31	\$ 64	\$ 268	\$ 69	\$ 287
4.2.5.4.1	Machine Mixer Blocks, Feed, WG, Lenses	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.2.5.4.2	Assemble Modules	0	0	6	12	\$ 117	\$ 20	\$ -	\$ 2	\$ 23	\$ 135	\$ 25	\$ 145
4.2.5.5	Install SIS Mixer and Test	0	0	42	84	\$ 819	\$ 80	\$ -	\$ 100	\$ 117	\$ 799	\$ 131	\$ 898
4.2.5.6	Deliver 163-211 GHz Receiver Modules	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.2.5.6.1	Deliver Modules #1-5	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.2.5.6.2	Deliver Modules #6-30	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.2.5.6.3	Deliver Modules #31-40	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.2.6	385-500 GHz Receiver Module	0	0	60	48	\$ 819	\$ 500	\$ -	\$ 1,319	\$ -	\$ -	\$ -	\$ -
4.2.6.1	SIS Mixer	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.2.6.1.1	Design, Fabricate & Test Mixer Design	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.2.6.1.2	Deliver Production Design	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.2.6.1.3	Fabricate Production Mixers	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.2.6.2	Design and Verify Optics	0	0	6	0	\$ 59	\$ 50	\$ -	\$ 109	\$ -	\$ -	\$ -	\$ -
4.2.6.3	Design Module	0	0	6	0	\$ 59	\$ 50	\$ -	\$ 109	\$ -	\$ -	\$ -	\$ -
4.2.6.4	Contract Fabrication	0	0	0	10	\$ 49	\$ 250	\$ -	\$ 299	\$ -	\$ -	\$ -	\$ -
4.2.6.4.1	Machine Mixer Blocks, Feed, WG, Lenses	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.2.6.4.2	Assemble Modules	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.2.6.5	Install SIS Mixer and Test	0	0	48	96	\$ 936	\$ 100	\$ -	\$ 1,036	\$ -	\$ -	\$ -	\$ -
4.2.6.6	Deliver 385-500 GHz Receiver Modules	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.2.6.6.1	Deliver Modules #1-5	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.2.6.6.2	Deliver Modules #6-30	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.2.6.6.3	Deliver Modules #31-40	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -

Millimeter Array
Construction:
Project Totals

4.2.7	125-163 GHz Receiver Module	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.2.7.1	SIS Mixer	0	0	48	48	\$ 702	\$ 500	\$ -	\$ -	\$ 128	\$ 217	\$ 1,074	\$ 238	\$ 1,183	\$ -
4.2.7.1.1	Design, Fabricate & Test Mixer Design	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.2.7.1.2	Deliver Production Design	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.2.7.1.3	Fabricate Production Mixers	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.2.7.2	Design & Verify Optics	0	0	6	0	\$ 59	\$ 50	\$ -	\$ -	\$ 12	\$ 16	\$ 96	\$ 17	\$ 101	\$ -
4.2.7.3	Design Module	0	0	6	0	\$ 59	\$ 50	\$ -	\$ -	\$ 12	\$ 16	\$ 96	\$ 17	\$ 101	\$ -
4.2.7.4	Contract Fabrication	0	0	0	8	\$ 39	\$ 200	\$ -	\$ -	\$ 27	\$ 58	\$ 212	\$ 65	\$ 237	\$ -
4.2.7.4.1	Machine Mixer Blocks, Feed, WG, Lenses	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.2.7.4.2	Assemble Modules	0	0	0	2	\$ 10	\$ 50	\$ -	\$ -	\$ 7	\$ 14	\$ 53	\$ 15	\$ 57	\$ -
4.2.7.5	Install SIS Mixer and Test	0	0	48	96	\$ 936	\$ 100	\$ -	\$ -	\$ 115	\$ 136	\$ 921	\$ 156	\$ 1,055	\$ -
4.2.7.6	Deliver 125-163 GHz Receiver Modules	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.2.7.6.1	Deliver 125-163 GHz Modules #1-5	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.2.7.6.2	Deliver 125-163 GHz Modules #6-30	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.2.7.6.3	Deliver 125-163 GHz Modules #31-40	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.3	HFET Receiver Modules	0	0	35	69	\$ 678	\$ 339	\$ -	\$ -	\$ 100	\$ 138	\$ 917	\$ 144	\$ 957	\$ -
4.3.1	Contract for HFET Wafer	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.3.2	Receive Diced HFET Wafer	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.3.3	33-45 GHz Module	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.3.3.1	Design Module	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.3.3.2	Design & Verify Optics	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.3.3.3	Contract Fabrication	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.3.3.3.1	Machine Blocks, Feed, WG, Lenses	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.3.3.3.2	Assemble Modules	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.3.3.3.3	Flip-in Mirror	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.3.4	Install HFET & Test Modules	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.3.5	Deliver 33-45 GHz Receiver Modules	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.3.5.1	Deliver Modules #1-20	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.3.5.2	Deliver Modules #21-40	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.3.6	67-95 GHz Module	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.3.6.1	Design Amplifier	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.3.6.2	Design Module	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.3.6.3	Design & Verify Optics	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.3.6.4	Contract Fabrication	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.3.6.4.1	Machine Blocks, Feed, WG, Lenses	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.3.6.4.2	Assemble Modules	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.3.6.5	Install HFET & Test Modules	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.3.6.6	Deliver 67-95 GHz Receiver Modules	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.3.6.6.1	Deliver Modules 67-95GHz #1-20	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
4.3.6.6.2	Deliver Modules 67-95GHz #21-40	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5	LO System	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.1	LO Reference: Prototype Systems	0	0	12	12	\$ 176	\$ 200	\$ -	\$ -	\$ -	\$ 56	\$ 376	\$ 56	\$ 376	\$ -
5.1.1	Deliver: Bench Prototype	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.1.2	Testing and Design Refinement	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.1.3	Procure/Fab Field Prototypes	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.1.4	Deliver: LO Ref Field Prototypes	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.1.5	Field Prototype testing and Design Refinement	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.1.6	Preproduction Review	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -

Millimeter Array
Construction:
Project Totals

5.1.7	Final Documentation and Design Modifications	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.1.8	Release for Manufacture	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.2	LO Reference: Production System	0	0	72	252	\$ 1,931	\$ -	\$ -	\$ -	\$ -	\$ 290	\$ 1,931	\$ -	\$ 318	\$ 2,118	\$ -	\$ -	\$ -
5.1.1	Production test and lab equipment	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.1.2	H-maser Frequency Standard (& Rb)	0	0	0	0	\$ -	\$ 300	\$ -	\$ 33	\$ 40	\$ 267	\$ -	\$ 42	\$ 280	\$ -	\$ -	\$ -	\$ -
5.1.3	8 GHz PL Oscillator & Distributor	0	0	0	0	\$ -	\$ 8	\$ -	\$ 1	\$ 1	\$ 7	\$ -	\$ 2	\$ 8	\$ -	\$ -	\$ -	\$ -
5.1.4	10 GHz PL Oscillator & Distributor	0	0	0	0	\$ -	\$ 10	\$ -	\$ 1	\$ 2	\$ 9	\$ -	\$ 2	\$ 9	\$ -	\$ -	\$ -	\$ -
5.1.5	12 GHz PL Oscillator & Distributor	0	0	0	0	\$ -	\$ 10	\$ -	\$ 1	\$ 2	\$ 9	\$ -	\$ 2	\$ 9	\$ -	\$ -	\$ -	\$ -
5.1.6	14 GHz PL Oscillator & Distributor	0	0	0	0	\$ -	\$ 10	\$ -	\$ 1	\$ 2	\$ 9	\$ -	\$ 2	\$ 9	\$ -	\$ -	\$ -	\$ -
5.1.7	3.2-5.2 GHz Synthesizer	0	0	0	0	\$ -	\$ 80	\$ -	\$ 9	\$ 16	\$ 71	\$ -	\$ 17	\$ 76	\$ -	\$ -	\$ -	\$ -
5.1.8	3.2 -5.2 GHz PLO and Fringe Generator	0	0	0	0	\$ -	\$ 1,600	\$ -	\$ 178	\$ 323	\$ 1,422	\$ -	\$ 340	\$ 1,514	\$ -	\$ -	\$ -	\$ -
5.1.9	Sampler Clock 4 GHz PL Osc & Distributor	0	0	0	0	\$ -	\$ 8	\$ -	\$ 1	\$ 1	\$ 7	\$ -	\$ 2	\$ 8	\$ -	\$ -	\$ -	\$ -
5.1.10	LO Ref Generator	0	0	0	0	\$ -	\$ 18	\$ -	\$ 2	\$ 4	\$ 16	\$ -	\$ 4	\$ 17	\$ -	\$ -	\$ -	\$ -
5.1.11	LO Ref Distributor - Control Bldg	0	0	0	0	\$ -	\$ 8	\$ -	\$ 1	\$ 1	\$ 7	\$ -	\$ 2	\$ 8	\$ -	\$ -	\$ -	\$ -
5.1.12	Microwave Round-trip Phase Measurement	0	0	0	0	\$ -	\$ 600	\$ -	\$ 67	\$ 121	\$ 533	\$ -	\$ 127	\$ 568	\$ -	\$ -	\$ -	\$ -
5.1.13	10-15 GHz Frequency Synthesizer	0	0	0	0	\$ -	\$ 1,000	\$ -	\$ 111	\$ 202	\$ 889	\$ -	\$ 212	\$ 946	\$ -	\$ -	\$ -	\$ -
5.1.14	First LO Fringe Generator	0	0	0	0	\$ -	\$ 200	\$ -	\$ 22	\$ 40	\$ 178	\$ -	\$ 42	\$ 189	\$ -	\$ -	\$ -	\$ -
5.1.15	16 GHz PL Oscillator	0	0	0	0	\$ -	\$ 400	\$ -	\$ 44	\$ 81	\$ 356	\$ -	\$ 85	\$ 379	\$ -	\$ -	\$ -	\$ -
5.1.16	26 GHz PL Oscillator	0	0	0	0	\$ -	\$ 400	\$ -	\$ 44	\$ 81	\$ 356	\$ -	\$ 85	\$ 379	\$ -	\$ -	\$ -	\$ -
5.1.17	LO Ref Distributor - Antenna	0	0	0	0	\$ -	\$ 200	\$ -	\$ 22	\$ 40	\$ 178	\$ -	\$ 42	\$ 189	\$ -	\$ -	\$ -	\$ -
5.1.18	VXCO Clean-up Loop	0	0	0	0	\$ -	\$ 200	\$ -	\$ 22	\$ 40	\$ 178	\$ -	\$ 42	\$ 189	\$ -	\$ -	\$ -	\$ -
5.1.19	Power supply module	0	0	0	0	\$ -	\$ 600	\$ -	\$ 67	\$ 121	\$ 533	\$ -	\$ 127	\$ 568	\$ -	\$ -	\$ -	\$ -
5.1.20	Bins / Racks (assemble and test)	0	0	0	0	\$ -	\$ 160	\$ -	\$ 18	\$ 32	\$ 142	\$ -	\$ 34	\$ 151	\$ -	\$ -	\$ -	\$ -
5.3	Millimeter LO Drivers	0	0	3	0	\$ 29	\$ 50	\$ -	\$ -	\$ 19	\$ 79	\$ -	\$ 22	\$ 90	\$ -	\$ -	\$ -	\$ -
5.3.1	Design and System Integration	0	0	15	0	\$ 146	\$ 50	\$ -	\$ -	\$ 37	\$ 196	\$ -	\$ 40	\$ 209	\$ -	\$ -	\$ -	\$ -
5.3.2	72-95 GHz Source	0	0	12	22	\$ 224	\$ 420	\$ -	\$ 72	\$ 138	\$ 573	\$ -	\$ 140	\$ 582	\$ -	\$ -	\$ -	\$ -
5.3.2.1	Contract Procurement and Fabrication	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.3.2.1.1	YIG-tuned Oscillator	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.3.2.1.2	18.00 - 23.75 GHz 10 db Amplifier	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.3.2.1.3	18.00 - 23.75 GHz x2 Multiplier	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.3.2.1.4	36.0 - 47.5 GHz 10 db Amplifier	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.3.2.1.5	36.0 - 47.5 GHz x2 Multiplier	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.3.2.1.6	Mount and Tuning circuitry	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.3.2.2	Assembly and Test	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.3.2.3	Deliver 72 - 95 GHz LO Sources	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.3.2.3.1	Deliver Modules #1-6	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.3.2.3.2	Deliver Modules #7-24	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.3.2.3.3	Deliver Modules #25-40	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.3.3	100-120 GHz Source	0	0	12	22	\$ 224	\$ 420	\$ -	\$ 644	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.3.3.1	Contract Procurement and Fabrication	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.3.3.1.1	YIG-tuned Oscillator	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.3.3.1.2	25.00 - 30.00 GHz 10 db Amplifier	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.3.3.1.3	15.00 - 30.00 GHz x2 Multiplier	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.3.3.1.4	50.0 - 60.0 GHz 10 db Amplifier	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.3.3.1.5	50-60 GHz x2 Multiplier	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.3.3.1.6	Mount and Tuning circuitry	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.3.3.2	Assembly and Test	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.3.3.3	Deliver 100 - 120 GHz LO Sources	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.3.3.3.1	Deliver Modules #1-3	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.3.3.3.2	Deliver Modules #4-21	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.3.3.3.3	Deliver Modules #22-40	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -

Millimeter Array
Construction:
Project Totals

5.3.4	87 - 108 GHz Source	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
		0	0	15	19	\$	239	\$	480	\$	75	\$	157	\$	644	\$	168	\$	687
5.3.4.1	Contract Procurement and Fabrication	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
5.3.4.1.1	YIG-tuned Oscillator	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
5.3.4.1.2	21.75-27.00 GHz 10 db Amplifier	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
5.3.4.1.3	21.75-27.00 GHz x2 Multiplier	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
5.3.4.1.4	43.5-54.0 GHz 10 db Amplifier	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
5.3.4.1.5	43.5-54.0 GHz x2 Multiplier	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
5.3.4.1.6	Mount and Tuning Circuitry	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
5.3.4.2	Assembly and Test	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
5.3.4.3	Deliver 87 - 108 GHz LO Sources	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
5.3.4.3.1	Deliver Modules #1-6	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
5.3.4.3.2	Deliver Modules #7-20	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
5.3.4.3.3	Deliver Modules #21-35	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
5.3.4.3.4	Deliver Modules #36-40	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
5.3.5	65 - 85 GHz Source	0	0	15	19	\$	239	\$	480	\$	75	\$	157	\$	644	\$	168	\$	687
5.3.5.1	Contract Procurement and Fabrication	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
5.3.5.1.1	YIG-tuned Oscillator	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
5.3.5.1.2	16.25-21.25 GHz 10 db Amplifier	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
5.3.5.1.3	16.25-21.25 GHz x2 Multiplier	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
5.3.5.1.4	32.5-42.5 GHz 10 db Amplifier	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
5.3.5.1.5	32.5-42.5 GHz x2 Multiplier	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
5.3.5.1.6	Mount and Tuning Circuitry	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
5.3.5.2	Assembly and Test	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
5.3.5.3	Deliver 65 - 85 GHz LO Sources	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
5.3.5.3.1	Deliver Modules #1-6	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
5.3.5.3.2	Deliver Modules #7-20	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
5.3.5.3.3	Deliver Modules #21-35	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
5.3.5.3.4	Deliver Modules #36-40	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
5.4	Millimeter LO Multiplier Chains	0	0	2	0	\$	20	\$	-	\$	-	\$	3	\$	20	\$	3	\$	22
5.4.1	Design and System Integration	0	0	38	36	\$	546	\$	300	\$	167	\$	147	\$	679	\$	149	\$	685
5.4.2	211 - 275 GHz Receiver LO	0	0	12	60	\$	410	\$	175	\$	65	\$	94	\$	520	\$	99	\$	544
5.4.2.1	Contract Fabrication	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
5.4.2.1.1	X3 Diode for 72-95 GHz Source	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
5.4.2.1.2	Machine Mount	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
5.4.2.1.3	Bias and Control circuits	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
5.4.2.2	Assemble Multiplier and Test	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
5.4.2.3	Integrate Source and Multiplier; test	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
5.4.2.4	Deliver 211-275 GHz Rcvr LO Modules	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
5.4.2.4.1	Deliver Modules #1-3	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
5.4.2.4.2	Deliver Modules #4-21	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
5.4.2.4.3	Deliver Modules #22-40	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
5.4.3	602 - 720 GHz Receiver LO	0	0	12	60	\$	410	\$	175	\$	585	\$	-	\$	-	\$	-	\$	-
5.4.3.1	Contract Fabrication	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
5.4.3.1.1	X2 Diode for 100-120 GHz Source	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
5.4.3.1.2	X3 Diode for 200-240 GHz Input	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
5.4.3.1.3	Machine Mount	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
5.4.3.1.4	Bias and Control circuits	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
5.4.3.2	Assemble Multipliers and Test	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
5.4.3.3	Integrate Source and Multipliers; test	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-

Millimeter Array
Construction:
Project Totals

5.4.3.4	Deliver 602-720 GHz Rcvr LO Modules	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.4.3.4.1	Deliver Modules #1-6	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.4.3.4.2	Deliver Modules #7-18	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.4.3.4.3	Deliver Modules #19-34	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.4.3.4.4	Deliver Modules #35-40	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.4.4	275 - 370 GHz Receiver LO	0	0	12	51	\$ 366	\$ 145	\$ -	\$ -	\$ 57	\$ 81	\$ 454	\$ 86	\$ -	\$ -	\$ -	\$ -	\$ 479
5.4.4.1	Contract Fabrication	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.4.4.1.1	X2 Diode for 72-95 GHz Source	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.4.4.1.2	X2 Diode for 144-190 GHz Input	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.4.4.1.3	Machine Mount	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.4.4.1.4	Bias and Control Circuits	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.4.4.2	Assemble Multipliers and Test	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.4.4.3	Integrate Source and Multipliers; test	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.4.4.4	Deliver 275-370 GHz Rcvr LO Modules	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.4.4.4.1	Deliver Modules #1-6	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.4.4.4.2	Deliver Modules #7-27	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.4.4.4.3	Deliver Modules #28-40	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.4.5	163 - 211 GHz Receiver LO	0	0	18	81	\$ 570	\$ 245	\$ -	\$ -	\$ 91	\$ 132	\$ 725	\$ 142	\$ -	\$ -	\$ -	\$ -	\$ 781
5.4.5.1	Contract Fabrication	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.4.5.1.1	X2 Diode for 87-108 GHz Source	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.4.5.1.2	Machine Mount	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.4.5.1.3	Bias and Control Circuits	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.4.5.2	Assemble Multiplier and Test	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.4.5.3	Integrate Source and Multiplier; test	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.4.5.4	Deliver 163 - 211 GHz Rcvr LO Modules	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.4.5.4.1	Deliver Modules #1-6	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.4.5.4.2	Deliver Modules #7-24	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.4.5.4.3	Deliver Modules #25-40	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.4.6	385 - 500 GHz Receiver LO	0	0	15	72	\$ 497	\$ 225	\$ -	\$ -	\$ 303	\$ 78	\$ 419	\$ 86	\$ -	\$ -	\$ -	\$ -	\$ 462
5.4.6.1	Contract Fabrication	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.4.6.1.1	X3 Diode for 65-85 GHz Source	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.4.6.1.2	X2 Diode for 130-170 GHz Input	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.4.6.1.3	Machine Mount	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.4.6.1.4	Bias and Control Circuits	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.4.6.2	Assemble Multiplier and test	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.4.6.3	Integrate source and Multiplier; test	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.4.6.4	Deliver 385-500 GHz Rcvr LO Modules	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.4.6.4.1	Deliver Modules #1-6	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.4.6.4.2	Deliver Modules #7-24	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.4.6.4.3	Deliver Modules #25-40	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.4.7	125 - 163 GHz Receiver LO	0	0	21	78	\$ 585	\$ 200	\$ -	\$ -	\$ 87	\$ 122	\$ 698	\$ 135	\$ -	\$ -	\$ -	\$ -	\$ 773
5.4.7.1	Contract Fabrication	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.4.7.1.1	X2 Diode for 65 - 85 GHz Source	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.4.7.1.2	Machine Mount	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.4.7.1.3	Bias and Control Circuits	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.4.7.2	Assemble Multiplier and test	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.4.7.3	Integrate Source and Multiplier; test	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.4.7.4	Deliver 125-163 GHz Rcvr LO Modules	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.4.7.4.1	Deliver Modules #1-6	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -

Millimeter Array
Construction:
Project Totals

5.4.7.4.2	Deliver Modules #7-18	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.4.7.4.3	Deliver Modules #19-34	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.4.7.4.4	Deliver Modules #35-40	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
5.4.8	33-45 GHz Receiver LO	0	0	3	6	\$ 59	\$ 25	\$ -	\$ -	\$ 9	\$ 13	\$ 74	\$ 14	\$ 76	\$ -	\$ -	\$ -	\$ -
5.4.8.1	Design & Fab Selection & Coupling from Sources	0	0	3	6	\$ 59	\$ 25	\$ -	\$ -	\$ -	\$ 13	\$ 84	\$ 13	\$ 84	\$ -	\$ -	\$ -	\$ -
		0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
6	IF System	0	0	72	192	\$ 1,638	\$ -	\$ -	\$ -	\$ -	\$ 246	\$ 1,638	\$ 269	\$ 1,795	\$ -	\$ -	\$ -	\$ -
6.1	IF System: Prototype Systems	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
6.1.1	Deliver (Bench) Prototype IF System	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
6.1.2	Testing and Design Refinement	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
6.1.3	Procure/Fab Field Prototypes	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
6.1.4	Deliver IF Field Prototypes to Test Interfeometer	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
6.1.5	Field Prototype testing and Design Refinement	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
6.1.6	Preproduction Review	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
6.1.7	Final Documentation and Design Modifications	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
6.1.8	Release for Manufacture	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
6.2	Production test and lab equipment	0	0	12	12	\$ 176	\$ 200	\$ -	\$ -	\$ -	\$ 56	\$ 376	\$ 56	\$ 376	\$ -	\$ -	\$ -	\$ -
6.3	IF Multiplexer	0	0	0	0	\$ -	\$ 1,600	\$ -	\$ -	\$ 178	\$ 213	\$ 1,422	\$ 227	\$ 1,514	\$ -	\$ -	\$ -	\$ -
6.4	IF Demultiplexer	0	0	0	0	\$ -	\$ 800	\$ -	\$ -	\$ 89	\$ 107	\$ 711	\$ 114	\$ 757	\$ -	\$ -	\$ -	\$ -
6.5	IF Matrix Switch	0	0	0	0	\$ -	\$ 640	\$ -	\$ -	\$ 71	\$ 85	\$ 569	\$ 91	\$ 606	\$ -	\$ -	\$ -	\$ -
6.6	Baseband Converter	0	0	0	0	\$ -	\$ 1,600	\$ -	\$ -	\$ 178	\$ 213	\$ 1,422	\$ 227	\$ 1,514	\$ -	\$ -	\$ -	\$ -
6.7	Power supply module	0	0	0	0	\$ -	\$ 400	\$ -	\$ -	\$ 44	\$ 53	\$ 356	\$ 57	\$ 379	\$ -	\$ -	\$ -	\$ -
6.8	Bins / Racks (assemble and test)	0	0	0	0	\$ -	\$ 160	\$ -	\$ -	\$ 18	\$ 21	\$ 142	\$ 23	\$ 151	\$ -	\$ -	\$ -	\$ -
		0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
7	Optical Fiber System	0	0	72	192	\$ 1,638	\$ -	\$ -	\$ -	\$ -	\$ 246	\$ 1,638	\$ 269	\$ 1,795	\$ -	\$ -	\$ -	\$ -
7.1	Optical Fiber System: Prototype Systems	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
7.1.1	Deliver (Bench) Prototype FO System	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
7.1.2	Testing and Design Refinement	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
7.1.3	Procure/Fab Field Prototypes	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
7.1.4	Deliver FO Field Prototypes to Test Interfeometer	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
7.1.5	Field Prototype testing and Design Refinement	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
7.1.6	Preproduction Review	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
7.1.7	Final Documentation and Design Modifications	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
7.1.8	Release for Manufacture	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
7.1	Production test and lab equipment	0	0	12	12	\$ 176	\$ 200	\$ -	\$ -	\$ -	\$ 56	\$ 376	\$ 56	\$ 376	\$ -	\$ -	\$ -	\$ -
7.2	IF TX / RX	0	0	0	0	\$ -	\$ 2,400	\$ -	\$ -	\$ 267	\$ 320	\$ 2,133	\$ 341	\$ 2,271	\$ -	\$ -	\$ -	\$ -
7.3	LO Reference TX / RX	0	0	0	0	\$ -	\$ 400	\$ -	\$ -	\$ 44	\$ 53	\$ 356	\$ 57	\$ 379	\$ -	\$ -	\$ -	\$ -
7.4	Microwave Round-trip Phase TX / RX	0	0	0	0	\$ -	\$ 400	\$ -	\$ -	\$ 44	\$ 53	\$ 356	\$ 57	\$ 379	\$ -	\$ -	\$ -	\$ -
7.5	Monitor / Control TX / RX	0	0	0	0	\$ -	\$ 200	\$ -	\$ -	\$ 22	\$ 27	\$ 178	\$ 28	\$ 189	\$ -	\$ -	\$ -	\$ -
7.6	Power supply module	0	0	0	0	\$ -	\$ 400	\$ -	\$ -	\$ 44	\$ 53	\$ 356	\$ 57	\$ 379	\$ -	\$ -	\$ -	\$ -
7.7	Bins / Racks (assemble and test)	0	0	0	0	\$ -	\$ 160	\$ -	\$ -	\$ 18	\$ 21	\$ 142	\$ 23	\$ 151	\$ -	\$ -	\$ -	\$ -
		0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
8	Correlator	0	0	216	216	\$ 3,159	\$ 8,000	\$ -	\$ -	\$ 1,240	\$ 2,244	\$ 9,919	\$ 2,378	\$ 10,467	\$ -	\$ -	\$ -	\$ -
8.1	Digital Sampler, 4 GHz	0	0	24	36	\$ 410	\$ 1,284	\$ -	\$ -	\$ 188	\$ 336	\$ 1,505	\$ 346	\$ 1,542	\$ -	\$ -	\$ -	\$ -
8.1.1	Refine Design	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
8.1.2	Release Digital Sampler for Manufacture	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
8.1.3	Contract Materials	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
8.1.4	Assembly	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
8.1.5	Validation and Delivery	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -

8.2	Digital FIR Filter	0	0	0	0	0	0	410	1,599					192	414	1,817	425	1,854
8.2.1	Prototype testing on Test Interferometer	0	0	0	0	0	0											
8.2.2	Design Refinement	0	0	0	0	0	0											
8.2.3	Release FIR Filter for manufacture	0	0	0	0	0	0											
8.2.4	Chip Fabrication	0	0	0	0	0	0											
8.2.5	Assembly	0	0	0	0	0	0											
8.2.6	Validation and Delivery	0	0	0	0	0	0											
8.3	Custom Boards	0	0	0	0	0	0											
8.3.1	Correlator Board	0	0	0	0	0	0											
8.3.1.1	Prototype assembly	0	0	0	0	0	0											
8.3.1.2	Prototype test	0	0	0	0	0	0											
8.3.1.3	Design modifications	0	0	0	0	0	0											
8.3.1.4	Fab, assemble and test with design mods	0	0	0	0	0	0											
8.4	Correlator Chip	0	0	0	0	0	0											
8.4.1	Prototype chip fabrication	0	0	0	0	0	0											
8.4.2	Prototype chip test	0	0	0	0	0	0											
8.4.3	Design modifications	0	0	0	0	0	0											
8.4.4	Fabricate and test design mods	0	0	0	0	0	0											
8.4.5	Fabricate production run	0	0	0	0	0	0											
8.5	Racks	0	0	0	0	0	0											
8.5.1	Design control wiring	0	0	0	0	0	0											
8.5.2	Design signal wiring	0	0	0	0	0	0											
8.5.3	Order parts	0	0	0	0	0	0											
8.5.4	Assemble prototypes	0	0	0	0	0	0											
8.6	Software	0	0	0	0	0	0											
8.7	Prototype Correlator Production	0	0	0	0	0	0											
8.7.1	Order parts	0	0	0	0	0	0											
8.7.2	Assemble	0	0	0	0	0	0											
8.7.3	Test	0	0	0	0	0	0											
8.7.4	Deliver Prototype Correlator to VLA site	0	0	0	0	0	0											
8.8	Site Correlator Production	0	0	0	0	0	0											
8.8.1	First 1/4 correlator	0	0	0	0	0	0											
8.8.1.1	Determine configuration	0	0	0	0	0	0											
8.8.1.2	Order parts	0	0	0	0	0	0											
8.8.1.3	Assemble	0	0	0	0	0	0											
8.8.1.4	Test	0	0	0	0	0	0											
8.8.1.5	Deliver 1/4 Correlator to MMA site	0	0	0	0	0	0											
8.8.2	Second 1/4 correlator	0	0	0	0	0	0											
8.8.2.1	Order parts	0	0	0	0	0	0											
8.8.2.2	Assemble	0	0	0	0	0	0											
8.8.2.3	Test	0	0	0	0	0	0											
8.8.2.4	Deliver 1/4 Correlator to MMA site	0	0	0	0	0	0											
8.8.3	Third 1/4 correlator	0	0	0	0	0	0											
8.8.3.1	Order parts	0	0	0	0	0	0											
8.8.3.2	Assemble	0	0	0	0	0	0											
8.8.3.3	Test	0	0	0	0	0	0											
8.8.3.4	Deliver 1/4 Correlator to MMA site	0	0	0	0	0	0											
8.8.4	Fourth 1/4 correlator	0	0	0	0	0	0											
8.8.4.1	Order parts	0	0	0	0	0	0											
8.8.4.2	Assemble	0	0	0	0	0	0											
8.8.4.3	Test	0	0	0	0	0	0											

Millimeter Array
Construction:
Project Totals

8.8.4.4	Deliver 1/4 Correlator to MMA site	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-		
8.9	Continued Support	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-		
		0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-		
		0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-		
9	Computing	0	0	0	0	\$	-	\$	1,250	\$	-	\$	-	\$	375	\$	1,250	\$	415	\$	1,383
9.1	Control Software	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
9.1.1	Test Interferometer Control & Analysis	0	33	0	0	\$	286	\$	-	\$	-	\$	-	\$	43	\$	286	\$	43	\$	286
9.1.2	MMA correlator software	0	104	0	0	\$	901	\$	-	\$	-	\$	-	\$	135	\$	901	\$	137	\$	913
9.1.3	Multi-antenna & sub-array control	0	77	0	0	\$	667	\$	-	\$	-	\$	-	\$	100	\$	667	\$	106	\$	709
9.1.4	Operators & Observers interfaces	0	105	0	0	\$	910	\$	-	\$	-	\$	-	\$	137	\$	910	\$	142	\$	944
9.1.5	Deliver Control Software	0	50	0	0	\$	433	\$	-	\$	-	\$	-	\$	65	\$	433	\$	70	\$	464
9.1.6	Maintenance	0	120	0	0	\$	1,040	\$	-	\$	1,040	\$	-	\$	-	\$	-	\$	-	\$	-
9.2	Scheduling	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
9.2.1	Static scheduling system	0	39	0	0	\$	338	\$	-	\$	-	\$	-	\$	51	\$	338	\$	53	\$	351
9.2.2	Dynamic scheduling simulations	0	36	0	0	\$	312	\$	-	\$	-	\$	-	\$	47	\$	312	\$	47	\$	315
9.2.3	Dynamic scheduling prototype	0	20	0	0	\$	173	\$	-	\$	-	\$	-	\$	26	\$	173	\$	28	\$	184
9.2.4	Dynamic scheduling implementation	0	78	0	0	\$	676	\$	-	\$	-	\$	-	\$	101	\$	676	\$	115	\$	765
9.2.5	Initial Operations with Dynamic Scheduling	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
9.3	Proposal Preparation Software	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
9.3.1	Prototype	0	24	0	0	\$	208	\$	-	\$	-	\$	-	\$	31	\$	208	\$	32	\$	215
9.3.2	Production version	0	43	0	0	\$	373	\$	-	\$	-	\$	-	\$	56	\$	373	\$	62	\$	415
9.4	Image Pipeline	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
9.4.1	Automated calibration & imaging heuristics	0	13	0	0	\$	113	\$	-	\$	-	\$	-	\$	17	\$	113	\$	17	\$	114
9.4.2	Prototype image pipeline	0	60	0	0	\$	520	\$	-	\$	-	\$	-	\$	78	\$	520	\$	88	\$	584
9.4.3	Parallelization studies and implementation	0	24	0	0	\$	208	\$	-	\$	-	\$	-	\$	31	\$	208	\$	34	\$	227
9.4.4	Initial Image Pipeline Operations	0	20	0	0	\$	173	\$	-	\$	-	\$	-	\$	26	\$	173	\$	29	\$	191
9.4.5	Production image pipeline	0	20	0	0	\$	173	\$	-	\$	-	\$	-	\$	26	\$	173	\$	29	\$	196
9.5	Archiving	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
9.5.1	Prototype distributed archive	0	30	0	0	\$	260	\$	-	\$	-	\$	-	\$	39	\$	260	\$	40	\$	267
9.5.2	Evaluate storage hardware	0	6	0	0	\$	52	\$	-	\$	-	\$	-	\$	8	\$	52	\$	9	\$	60
9.5.3	Production archive	0	100	0	0	\$	867	\$	-	\$	-	\$	-	\$	130	\$	867	\$	144	\$	957
9.5.4	Data Archive operational	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
9.6	Post-processing	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
9.6.1	Define MMA Data formats	0	12	0	0	\$	104	\$	-	\$	-	\$	-	\$	16	\$	104	\$	16	\$	108
9.6.2	MMA filler & format conversions	0	11	0	0	\$	95	\$	-	\$	-	\$	-	\$	14	\$	95	\$	15	\$	101
9.6.3	MMA-specific calibrations	0	13	0	0	\$	113	\$	-	\$	-	\$	-	\$	17	\$	113	\$	18	\$	118
9.6.4	MMA Post-processing begins	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
9.6.5	Maintenance	0	68	0	0	\$	589	\$	-	\$	537	\$	-	\$	8	\$	52	\$	8	\$	52
		0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
		0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
10	System Integration	0	0	0	0	\$	-	\$	125	\$	-	\$	-	\$	38	\$	125	\$	39	\$	130
10.4	Test Interferometer Site Preparation	0	0	0	4	\$	20	\$	40	\$	-	\$	-	\$	15	\$	60	\$	15	\$	60
10.4.1	Complete Office and Lab Space Preparation	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
10.4.2	Cabling	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
10.4.3	Test Interferometer Site Complete	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
10.10.4	Prototype Antenna Outfitting	0	0	0	18	\$	88	\$	50	\$	-	\$	-	\$	28	\$	138	\$	28	\$	138
10.10.4.1	Cabling	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
10.10.4.2	Instrumentation	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
10.10.4.3	Eval. Rcvr. #1 / Ant. #1 Integration	0	0	24	12	\$	293	\$	-	\$	-	\$	-	\$	44	\$	293	\$	45	\$	300
10.10.4.4	Antenna #1 Outfitting Complete	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
10.10.5	Integration Holography System/Antenna	0	0	0	2	\$	10	\$	-	\$	-	\$	-	\$	1	\$	10	\$	1	\$	10
10.10.6	Integration Metrology/Antenna	0	0	0	5	\$	24	\$	-	\$	-	\$	-	\$	4	\$	24	\$	4	\$	24
10.10.7	Antenna #1 Integration & Testing	0	0	0	7	\$	34	\$	-	\$	-	\$	-	\$	5	\$	34	\$	5	\$	34

Millimeter Array
Construction:
Project Totals

Sci Man Months PROG ENGR TECH Personnel M+S to ops adj scope Contingency Σ Inflated Contingency Inflated Sum

10.10.8	Prot. Rcvr. Test & Evaluation	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-			
10.10.9	Antenna #2 Outfitting	0	0	0	0	21	\$	102	\$	50	\$	-	\$	-	\$	30	\$	152	\$	30	\$	152
10.10.9.1	Cabling	0	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
10.10.9.2	Instrumentation	0	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
10.10.9.3	Eval. Rcvr. #2 / Ant. #2 Integration	0	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
10.10.9.4	Antenna #2 Outfitting Complete	0	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
10.11	Test Interferometer	0	0	6	24	12	\$	345	\$	-	\$	-	\$	-	\$	52	\$	345	\$	53	\$	353
10.11.1	Antenna Evaluation & Characterization	0	0	0	6	0	\$	59	\$	-	\$	-	\$	-	\$	9	\$	59	\$	9	\$	61
10.11.1.1	Antenna Verification	0	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
10.11.1.4	Holography	0	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
10.11.1.5	Beam and Sidelobes	0	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
10.11.1.6	Gain vs. Elevation: Spillover Temp	0	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
10.11.1.7	Effect of Sun in & Near the Beam	0	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
10.11.2	Engineering Recommendations re Prod. Ant.	0	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
10.11.3	Revise Interface Specifications	0	0	3	0	0	\$	29	\$	-	\$	-	\$	-	\$	4	\$	29	\$	5	\$	31
10.11.5	Operations Personnel Training	0	0	0	0	0	\$	440	\$	-	\$	440	\$	-	\$	-	\$	-	\$	-	\$	-
10.11.5.1	Recruit Initial Chile Ops Staff	6	0	0	0	48	\$	283	\$	-	\$	283	\$	-	\$	-	\$	-	\$	-	\$	-
10.11.5.2	Array Operations	0	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
10.11.5.3	Engineering Maintenance	0	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
10.11.5.4	Scientific Support & Analysis	0	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
10.12.2	Relocate Ops Staff to Chile	0	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
10.8.4.6	Start On-site Operations	0	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
10.12	Disassemble Test Interferometer	0	0	0	0	24	\$	117	\$	-	\$	-	\$	-	\$	18	\$	117	\$	19	\$	129
10.12.1	Prepare & Ship Antenna #1, #2	0	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
10.12.3	Restore Facilities at VLA Site	0	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
10.13	On Site System Integration	0	0	0	0	192	\$	2,984	\$	-	\$	2,984	\$	-	\$	-	\$	-	\$	-	\$	-
		0	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
		0	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
		0	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
11	Calibration and Imaging	1	0	0	0	0	\$	8	\$	-	\$	-	\$	-	\$	1	\$	8	\$	1	\$	8
11.1	Radiometric Phase Design & Prototype	0	0	0	8	0	\$	78	\$	20	\$	-	\$	-	\$	18	\$	98	\$	18	\$	98
11.1.1	Complete 183GHz Phase Mon Prototype	0	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
11.1.2	Demo 183 GHz Phase Monitor Radiometer on-Site	0	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
11.1.3	Design Refinement	0	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
11.1.4	Release Phase Mon Radiometer for manufacture	0	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
11.2	Production Fab of Phase Monitor Radiometer	0	0	0	22	96	\$	683	\$	2,050	\$	-	\$	284	\$	632	\$	2,448	\$	665	\$	2,589
11.2.1	Contract Subassembly Fabrication	0	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
11.2.1.1	Radiometer & Local Oscillator	0	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
11.2.1.2	Spectrometer	0	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
11.2.1.3	Feed, Window, lens, instrumentation	0	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
11.2.1.4	M/C Interface	0	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
11.2.2	Assembly & Test	0	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
11.2.3	Deliver Production Radiometers	0	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
11.2.4	Integration in Receiver Package	0	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
11.2.5	Verification on-Site	0	0	0	0	3	\$	15	\$	-	\$	-	\$	-	\$	2	\$	15	\$	2	\$	17
11.3	Production Fabrication of Dual-load Amp Cal Sys	0	0	0	0	23	\$	112	\$	454	\$	-	\$	61	\$	135	\$	505	\$	140	\$	527
11.3.1	Design Refinement	0	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
11.3.2	Release Phase Mon Radiometer for manufacture	0	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
11.3.3	Contract Subassembly	0	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
11.3.3.1	Machining	0	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
11.3.3.2	Load Fabrication	0	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
11.3.3.3	Motors, Servo	0	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
11.3.3.4	M/C Interface	0	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-
11.3.4	Assembly & Test	0	0	0	0	0	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-	\$	-

Millimeter Array Construction: Project Totals

11.3.5	Integration on Production Antennas	0	0	0	0	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
11.4	Imaging Studies & Project Support	30-11 SJE 456	0	0	0	\$ 3,705	\$ -	\$ 3,120	\$ -	\$ 88	\$ 585	\$ 88	\$ 590
11.5	Imaging Algorithm Development	56	28	0	0	\$ 698	\$ -	\$ -	\$ -	\$ 105	\$ 698	\$ 113	\$ 752
TOTALS			0			\$ 69,866	\$ 215,054	\$ 13,908	\$ 30,554	\$ 51,975	\$ 240,457	\$ 56,735	\$ 256,884

Millimeter Array
Construction:
Project Totals

Millimeter Array Construction 2001

WBS	Name	Scientists Work-Months	Programmers Work-Months	Engineers Work-Months	Technicians Work-Months	Personnel Cost	Materials and Supplies	Transfer to Operations	Adjustment to Scope	Contingency	Sum Cost	Inflated Contingency	Inflated Sum
1	Administration												
1.1	Project Management	72			24	\$ 702				\$ 105	\$ 702	\$ 105	\$ 702
1.1.1	Management, Planning, and Oversight						\$ 500			\$ 75	\$ 500	\$ 75	\$ 500
1.1.2	Business Operations						\$ 40			\$ 6	\$ 40	\$ 6	\$ 40
1.1.3	Chilean Operations						\$ 50			\$ 8	\$ 50	\$ 8	\$ 50
1.1.4	Safety and Health												
1.1.5	Personnel												
1.1.6	Project Science Office												
1.1.7	AUI Management						\$ 350			\$ -	\$ 350	\$ -	\$ 350
1.2	Engineering			24	12	\$ 293	\$ 20			\$ 47	\$ 313	\$ 47	\$ 313
1.2.1	System Engineering--Phase II												
1.2.2	Documentation System												
1.2.3	Production Engineering												
1.3	US Facilities												
1.3.1	CDL Permanent Facilities						\$ 600			\$ -	\$ 600	\$ -	\$ 600
1.3.2	Manufacturing Facilities						\$ 100			\$ 15	\$ 100	\$ 15	\$ 100
1.3.3	Common Infrastructure						\$ 200			\$ 30	\$ 200	\$ 30	\$ 200
2	Site Development			12		\$ 117	\$ 50			\$ 25	\$ 167	\$ 25	\$ 167
2.1	Review Legalities Regarding Array and OSF Sites												
2.2	Maintain Mining claims						\$ 25			\$ -	\$ 25	\$ -	\$ 25
2.3	Contract A&E Studies						\$ 938		\$ 104	\$ 167	\$ 834	\$ 167	\$ 834
2.4	Hire Construction Manager for Chile												
2.5	Array Site												
2.5.1	Prepare Site Development Bid Packages												
2.5.1.1	Prepare Package for Array Site												
2.5.1.2	Review Bid Packages												
2.5.1.3	Bid Civil Works Construction												
2.5.2	Evaluate Array Site Bid Response												
2.5.2.1	Review Bids												
2.5.2.2	Recommend Contractors												
2.5.2.3	Award Array Site Contracts												
2.5.3	Contract Array Site Civil Works												
2.5.3.1	Array Site												
2.5.3.2	Inspect Completed Site Constr												
2.5.3.3	Accept Site Facility												
2.6	Operations Support Facility												
2.6.1	Prepare OSF Bid Packages												
2.6.1.1	Prepare Package for OSF												
2.6.1.2	Review Bid Packages												
2.6.1.3	Bid Civil Works Construction												
2.6.2	Evaluate OSF Bid Response												
2.6.2.1	Review Bids												
2.6.2.2	Recommend Contractors												
2.6.2.3	Award Contracts												

2.6.3	Contract OSF Civil Works																
2.6.3.1	Operations Support Facility																
2.6.3.2	Inspect Completed OSF Constr																
2.6.3.3	Accept OSF Facility																
2.7	OSF/Array Link																
2.7.1	Prepare OSF/Array Link Bid Package																
2.7.1.1	Prepare Package for OSF/Array F/O Link																
2.7.1.2	Review Bid Package																
2.7.1.3	Bid OSF/Array Link Construction																
2.7.2	Evaluate Bid Response																
2.7.2.1	Review Bids																
2.7.2.2	Recommend Contractors																
2.7.2.3	Award Contracts																
2.7.3	Contract Civil Works																
2.7.3.1	OSF/Array Link																
2.7.3.2	Inspect Completed OSF/Array Link Constr																
2.7.3.3	Accept OSF/Array Link																
2.8	Prepare for Instrument Assembly																
2.8.1	Equip Array Site																
2.8.2	Equip Operations Support Facility																
3	Antenna																
3.1	Antenna Engineering Support		48		\$	468			\$	70	\$	468	\$	70	\$	468	
3.3.40	Acceptance Tests Antenna #1																
3.3.45	Delivery of Antenna #1																
3.8.10	Sign Transporter Contract					\$	600			\$	180	\$	600	\$	180	\$	600
3.8.15	Transporter Acceptance tests																
3.8.20	Deliver/Accept Transporter #1																
3.7	Procurement of Antenna #2																
3.7.1	Antenna #2 Contract Supervision																
3.7.2	Antenna #2 Acceptance tests																
3.8	Negotiate Production Antenna Contract																
3.9	Sign Contract for Production Antennas																
3.10	Antenna Contract Supervision																
3.11	Accept Antenna #3 at OSF																
3.12	Prepare Antenna #3																
3.12.1	Outfit & Verify Ant #3 at OSF																
3.12.2	Move, Install & Verify Ant #3 on Site																
3.13	Accept Antenna #4 at OSF																
3.14	Prepare Antenna #4																
3.14.1	Outfit & Verify Ant #4 at OSF																
3.14.2	Move, Install & Verify Ant #4 on Site																
3.15	Accept Antenna#5 at OSF																
3.16	Prepare Antenna #5																
3.16.1	Outfit & Verify Ant #5 at OSF																
3.16.2	Move, Install & Verify Ant #5 on Site																
3.17	Accept Antenna#6 at OSF																
3.18	Prepare Antenna #6																
3.18.1	Outfit & Verify Ant #6 at OSF																
3.18.2	Move, Install & Verify Ant #6 on Site																

3.19	Accept Antenna #7 at OSF													
3.20	Prepare Antenna #7													
3.20.1	Outfit & Verify Ant #7 at OSF													
3.20.2	Move, Install & Verify Ant #7 on Site													
3.21	Accept Antenna #8 at OSF													
3.22	Prepare Antenna #8													
3.22.1	Outfit & Verify Ant #8 at OSF													
3.22.2	Move, Install & Verify Ant #8 on Site													
3.23	Accept Antenna #9 at OSF													
3.24	Prepare Antenna #9													
3.24.1	Outfit & Verify Ant #9 at OSF													
3.24.2	Move, Install & Verify Ant #9 on Site													
3.25	Accept Antenna #10 at OSF													
3.26	Prepare Antenna #10													
3.26.1	Outfit & Verify Ant #10 at OSF													
3.26.2	Move, Install and Verify Ant #10 on Site													
3.27	Accept Antenna #11 at OSF													
3.28	Prepare Antenna #11													
3.28.1	Outfit & Verify Ant #11 at OSF													
3.28.2	Move, Install & Verify Ant #11 on Site													
3.29	Accept Antenna #12 at OSF													
3.30	Prepare Antenna #12													
3.30.1	Outfit & Verify Ant #12 at OSF													
3.30.2	Move, Install & Verify Ant #12 on Site													
3.31	Accept Antenna #13 at OSF													
3.32	Prepare Antenna #13													
3.32.1	Outfit & Verify Ant #13 at OSF													
3.32.2	Move, Install & Verify Ant #13 on Site													
3.33	Accept Antenna #14 at OSF													
3.34	Prepare Antenna #14													
3.34.1	Outfit & Verify Ant #14 at OSF													
3.34.2	Move, Install & Verify Ant #14 on Site													
3.35	Accept Antenna #15 at OSF													
3.36	Prepare Antenna #15													
3.36.1	Outfit & Verify Ant #15 at OSF													
3.36.2	Move, Install & Verify Ant #15 on Site													
3.37	Accept Antenna #16 at OSF													
3.38	Prepare Antenna #16													
3.38.1	Outfit & Verify Ant #16 at OSF													
3.38.2	Move, Install & Verify Ant #16 on Site													
3.39	Accept Antenna #17 at OSF													
3.40	Prepare Antenna #17													
3.40.1	Outfit & Verify Ant #17 at OSF													
3.40.2	Move, Install & Verify Ant #17 on Site													
3.41	Accept Antenna #18 at OSF													
3.42	Prepare Antenna #18													
3.42.1	Outfit & Verify Ant #18 at OSF													
3.42.2	Move, Install & Verify Ant #18 on Site													
3.43	Accept Antenna #19 at OSF													
3.44	Prepare Antenna #19													
3.44.1	Outfit & Verify Ant #19 at OSF													
3.44.2	Move, Install & Verify Ant #19 on Site													
3.45	Accept Antenna #20 at OSF													

3.46	Prepare Antenna #20																		
3.46.1	Outfit & Verify Ant #20 at OSF																		
3.46.2	Move, Install & Verify Ant #20 on Site																		
3.47	Accept Antenna #21 at OSF																		
3.48	Prepare Antenna #21																		
3.48.1	Outfit & Verify Ant #21 at OSF																		
3.48.2	Move, Install & Verify Ant #21 on Site																		
3.49	Accept Antenna #22 at OSF																		
3.50	Prepare Antenna #22																		
3.50.1	Outfit & Verify Ant #22 at OSF																		
3.50.2	Move, Install & Verify Ant #22 on Site																		
3.51	Accept Antenna #23 at OSF																		
3.52	Prepare Antenna #23																		
3.52.1	Outfit & Verify Ant #23 at OSF																		
3.52.2	Move, Install & Verify Ant #23 on Site																		
3.53	Accept Antenna #24 at OSF																		
3.54	Prepare Antenna #24																		
3.54.1	Outfit & Verify Ant #24 at OSF																		
3.54.2	Move, Install & Verify Ant #24 on Site																		
3.55	Accept Antenna #25 at OSF																		
3.56	Prepare Antenna #25																		
3.56.1	Outfit & Verify Ant #25 at OSF																		
3.56.2	Move, Install & Verify Ant #25 on Site																		
3.57	Accept Antenna #26 at OSF																		
3.58	Prepare Antenna #26																		
3.58.1	Outfit & Verify Ant #26 at OSF																		
3.58.2	Move, Install & Verify Ant #26 on Site																		
3.59	Accept Antenna #27 at OSF																		
3.60	Prepare Antenna #27																		
3.60.1	Outfit & Verify Ant #27 at OSF																		
3.60.2	Move, Install & Verify Ant #27 on Site																		
3.61	Accept Antenna #28 at OSF																		
3.62	Prepare Antenna #28																		
3.62.1	Outfit & Verify Ant #28 at OSF																		
3.62.2	Move, Install & Verify Ant #28 on Site																		
3.63	Accept Antenna #29 at OSF																		
3.64	Prepare Antenna #29																		
3.64.1	Outfit & Verify Ant #29 at OSF																		
3.64.2	Move, Install & Verify Ant #29 on Site																		
3.65	Accept Antenna #30 at OSF																		
3.66	Prepare Antenna #30																		
3.66.1	Outfit & Verify Ant #30 at OSF																		
3.66.2	Move, Install & Verify Ant #30 on Site																		
3.67	Accept Antenna #31 at OSF																		
3.68	Prepare Antenna #31																		
3.68.1	Outfit & Verify Ant #31 at OSF																		
3.68.2	Move, Install and Verify Ant #31 on Site																		
3.69	Accept Antenna #32 at OSF																		
3.70	Prepare Antenna #32																		
3.70.1	Outfit & Verify Ant #32 at OSF																		
3.70.2	Move, Install & Verify Ant #32 on Site																		
3.71	Accept Antenna #33 at OSF																		
3.72	Prepare Antenna #33																		

3.72.1	Outfit & Verify Ant #33 at OSF																			
3.72.2	Move, Install and Verify Ant #33 on Site																			
3.73	Accept Antenna #34 at OSF																			
3.74	Prepare Antenna #34																			
3.74.1	Outfit & Verify Ant #34 at OSF																			
3.74.2	Move, Install and Verify Ant #34 on Site																			
3.75	Accept Antenna #35 at OSF																			
3.76	Prepare Antenna #35																			
3.76.1	Outfit & Verify Ant #35 at OSF																			
3.76.2	Move, Install & Verify Ant #35 on Site																			
3.77	Accept Antenna #36 at OSF																			
3.78	Prepare Antenna #36																			
3.78.1	Outfit & Verify Ant #36 at OSF																			
3.78.2	Move, Install & Verify Ant #36 on Site																			
3.79	Prepare Antenna #1																			
3.79.1	Antenna #1 Reassembled at OSF																			
3.79.2	Outfit & Verify Ant #1 at OSF																			
3.79.3	Move, Install & Verify Ant #1 on Site																			
3.80	Prepare Antenna #2																			
3.80.1	Antenna #2 Reassembled at OSF																			
3.80.2	Outfit & Verify Ant #2 at OSF																			
3.80.3	Move, Install & Verify Ant #2 on Site																			
3.81	Antenna Transporter																			
3.81.1	Contract for Transporter #1 move to site																			
3.81.2	Contract for Transporters #2, #3																			
3.81.3	Accept Transporters #2, #3 at OSF																			
4	Receivers																			
4.1	Receiver Package																			
4.1.1	Prototype Production Receiver Cryogenics			12	12	\$	176	\$	100			\$	41	\$	276	\$	41	\$	276	
4.1.1.1	CDR: Cryogenics Development																			
4.1.1.2	Construct & test prototype cryogenics																			
4.1.1.3	Deliver Prototype Cryogenics Subsystem																			
4.1.2	Prototype Production Receiver Package			24	24	\$	351	\$	150			\$	75	\$	501	\$	75	\$	501	
4.1.2.1	Prototype Receiver Package Integration																			
4.1.2.2	Prot. Rcvr. Pckg Lab Test & Evaluation																			
4.1.2.3	Complete Prototype MMA Receiver Package																			
4.1.3	MMA Rcvr Pckg Design Refinement																			
4.1.4	Documentation																			
4.1.5	Release MMA Receiver Pckg for manufacture																			
4.1.6	Contract for Receiver Pckg Subassemblies																			
4.1.6.1	Machine Dewars																			
4.1.6.2	Fabricate Cryogenics subsystems																			
4.1.6.3	Fabricate windows, IR filters, etc																			
4.1.7	Accept Receiver Pckg Subassemblies																			
4.1.7.1	Subassemblies #1-6																			
4.1.7.2	Subassemblies #7-16																			
4.1.7.3	Subassemblies #17-26																			
4.1.7.4	Subassemblies #27-36																			
4.1.7.5	Subassemblies #37-40																			

4.1.8	Fab Rcvr Pckg Instrumentation & Electronics																			
4.1.9	Fabricate Receiver Inserts																			
4.1.10	Assemble Receiver Package																			
4.1.10.1	Integrate Rcvr Instrumentation & subass'y																			
4.1.10.2	Deliver Receiver Package #1-6																			
4.1.10.3	Deliver Receiver Package #7-16																			
4.1.10.4	Deliver Receiver Package #17-26																			
4.1.10.5	Deliver Receiver Package #27-36																			
4.1.10.6	Deliver Receiver Package #37-40																			
4.2	SIS Receiver Modules																			
4.2.1	211-275 GHz Module	24	24	\$	351	\$	400		\$	83	\$	148	\$	668	\$	148	\$	668		
4.2.1.1	SIS Mixer																			
4.2.1.1.1	Design, Fab and Test Mixer Design																			
4.2.1.1.2	Deliver Production Design																			
4.2.1.1.3	Fabricate Production Mixers																			
4.2.1.2	Design & Verify Optics	6		\$	59	\$	50				\$	24	\$	109	\$	24	\$	109		
4.2.1.3	Design Module	6		\$	59	\$	50				\$	24	\$	109	\$	24	\$	109		
4.2.1.4	Contract Fabrication		4	\$	20	\$	25				\$	10	\$	45	\$	10	\$	45		
4.2.1.4.1	Machine Mixer Blocks, Feed, WG, Lenses																			
4.2.1.4.2	Assemble Modules																			
4.2.1.5	Install SIS Mixer & Test Modules																			
4.2.1.6	Deliver 211-275 GHz Receiver Modules																			
4.2.1.6.1	Deliver Modules #1-7																			
4.2.1.6.2	Deliver Modules #8-26																			
4.2.1.6.3	Deliver Modules #27-40																			
4.2.2	602-720 GHz Module	24	24	\$	351	\$	400		\$	751	\$	-	\$	-	\$	-	\$	-		
4.2.2.1	SIS Mixer																			
4.2.2.1.1	Design, Fabricate and Test Mixer Design																			
4.2.2.1.2	Deliver Production Design																			
4.2.2.1.3	Fabricate Production Mixers																			
4.2.2.2	Design & Verify Optics	6		\$	59	\$	50		\$	109	\$	-	\$	-	\$	-	\$	-		
4.2.2.3	Design Module	6		\$	59	\$	50		\$	109	\$	-	\$	-	\$	-	\$	-		
4.2.2.4	Contract Fabrication		4	\$	20	\$	25		\$	45	\$	-	\$	-	\$	-	\$	-		
4.2.2.4.1	Machine Mixer Blocks, Feed, WG, Lenses																			
4.2.2.4.2	Assemble Modules																			
4.2.2.5	Install SIS Mixer and Test Modules																			
4.2.2.6	Deliver 602-720 GHz Receiver Modules																			
4.2.2.6.1	Deliver Modules #1-7																			
4.2.2.6.2	Deliver Modules #8-26																			
4.2.2.6.3	Deliver Modules #27-40																			
4.2.3	275-370 GHz Receiver Module																			
4.2.3.1	SIS Mixer																			
4.2.3.1.1	Design, Fabricate and Test Mixer Design																			
4.2.3.1.2	Deliver Production Design																			
4.2.3.1.3	Fabricate Production Mixers																			
4.2.3.2	Design & Verify Optics	4		\$	39	\$	50				\$	21	\$	89	\$	21	\$	89		
4.2.3.3	Design Module																			
4.2.3.4	Contract Fabrication																			
4.2.3.4.1	Machine Mixer Blocks, Feed, WG, Lenses																			
4.2.3.4.2	Assemble Modules																			

4.2.3.5	Install SIS Mixer and Test Modules																				
4.2.3.6	Deliver 275-370 GHz Receiver Module																				
4.2.3.6.1	Deliver Modules #1-5																				
4.2.3.6.2	Deliver Modules #6-30																				
4.2.3.6.3	Deliver Modules #30-40																				
4.2.4	91-119 GHz Receiver Module																				
4.2.4.1	SIS Mixer																				
4.2.4.1.1	Design, Fabricate & Test Mixer Design																				
4.2.4.1.2	Deliver Production Design																				
4.2.4.1.3	Fabricate Production Mixers																				
4.2.4.2	Design & Verify Optics				4		\$	39	\$	50				\$	21	\$	89	\$	21	\$	89
4.2.4.3	Design Module																				
4.2.4.4	Contract Fabrication																				
4.2.4.4.1	Machine Mixer Blocks, Feed, WG, Lenses																				
4.2.4.4.2	Assemble Modules																				
4.2.4.5	Install SIS Mixer and Test Modules																				
4.2.4.6	Deliver 91-119 GHz Receiver Modules																				
4.2.4.6.1	Deliver Modules #1-5																				
4.2.4.6.2	Deliver Modules #6-30																				
4.2.4.6.3	Deliver Modules # 31-40																				
4.2.5	163-211 GHz Receiver Module																				
4.2.5.1	SIS Mixer																				
4.2.5.1.1	Design, Fabricate & Test Mixer Design																				
4.2.5.1.2	Deliver Production Design																				
4.2.5.1.3	Fabricate Production Mixers																				
4.2.5.2	Design & Verify Optics																				
4.2.5.3	Design Module																				
4.2.5.4	Contract Fabrication																				
4.2.5.4.1	Machine Mixer Blocks, Feed, WG, Lenses																				
4.2.5.4.2	Assemble Modules																				
4.2.5.5	Install SIS Mixer and Test																				
4.2.5.6	Deliver 163-211 GHz Receiver Modules																				
4.2.5.6.1	Deliver Modules #1-5																				
4.2.5.6.2	Deliver Modules #6-30																				
4.2.5.6.3	Deliver Modules #31-40																				
4.2.6	385-500 GHz Receiver Module																				
4.2.6.1	SIS Mixer																				
4.2.6.1.1	Design, Fabricate & Test Mixer Design																				
4.2.6.1.2	Deliver Production Design																				
4.2.6.1.3	Fabricate Production Mixers																				
4.2.6.2	Design and Verify Optics																				
4.2.6.3	Design Module																				
4.2.6.4	Contract Fabrication																				
4.2.6.4.1	Machine Mixer Blocks, Feed, WG, Lenses																				
4.2.6.4.2	Assemble Modules																				
4.2.6.5	Install SIS Mixer and Test																				
4.2.6.6	Deliver 385-500 GHz Receiver Modules																				
4.2.6.6.1	Deliver Modules #1-5																				
4.2.6.6.2	Deliver Modules #6-30																				
4.2.6.6.3	Deliver Modules #31-40																				

4.2.7	125-163 GHz Receiver Module																											
4.2.7.1	SIS Mixer																											
4.2.7.1.1	Design, Fabricate & Test Mixer Design																											
4.2.7.1.2	Deliver Production Design																											
4.2.7.1.3	Fabricate Production Mixers																											
4.2.7.2	Design & Verify Optics																											
4.2.7.3	Design Module																											
4.2.7.4	Contract Fabrication																											
4.2.7.4.1	Machine Mixer Blocks, Feed, WG, Lenses																											
4.2.7.4.2	Assemble Modules																											
4.2.7.5	Install SIS Mixer and Test																											
4.2.7.6	Deliver 125-163 GHz Receiver Modules																											
4.2.7.6.1	Deliver 125-163 GHz Modules #1-5																											
4.2.7.6.2	Deliver 125-163 GHz Modules #6-30																											
4.2.7.6.3	Deliver 125-163 GHz Modules #31-40																											
4.3	HFET Receiver Modules		10		18		\$	185		\$	119				\$	34		\$	41		\$	270		\$	41		\$	270
4.3.1	Contract for HFET Wafer																											
4.3.2	Receive Diced HFET Wafer																											
4.3.3	33-45 GHz Module																											
4.3.3.1	Design Module																											
4.3.3.2	Design & Verify Optics																											
4.3.3.3	Contract Fabrication																											
4.3.3.3.1	Machine Blocks, Feed, WG, Lenses																											
4.3.3.3.2	Assemble Modules																											
4.3.3.3.3	Flip-in Mirror																											
4.3.4	Install HFET & Test Modules																											
4.3.5	Deliver 33-45 GHz Receiver Modules																											
4.3.5.1	Deliver Modules #1-20																											
4.3.5.2	Deliver Modules #21-40																											
4.3.6	67-95 GHz Module																											
4.3.6.1	Design Amplifier																											
4.3.6.2	Design Module																											
4.3.6.3	Design & Verify Optics																											
4.3.6.4	Contract Fabrication																											
4.3.6.4.1	Machine Blocks, Feed, WG, Lenses																											
4.3.6.4.2	Assemble Modules																											
4.3.6.5	Install HFET & Test Modules																											
4.3.6.6	Deliver 67-95 GHz Receiver Modules																											
4.3.6.6.1	Deliver Modules 67-95GHz #1-20																											
4.3.6.6.2	Deliver Modules 67-95GHz #21-40																											
5	LO System																											
5.1	LO Reference: Prototype Systems		12		12		\$	176		\$	200				\$	56		\$	376		\$	56		\$	376			
5.1.1	Deliver: Bench Prototype																											
5.1.2	Testing and Design Refinement																											
5.1.3	Procure/Fab Field Prototypes																											
5.1.4	Deliver: LO Ref Field Prototypes																											
5.1.5	Field Prototype testing and Design Refinement																											
5.1.6	Preproduction Review																											

5.1.7	Final Documentation and Design Modifications																						
5.1.8	Release for Manufacture																						
5.2	LO Reference: Production System																						
5.1.1	Production test and lab equipment																						
5.1.2	H-maser Frequency Standard (& Rb)																						
5.1.3	8 GHz PL Oscillator & Distributor																						
5.1.4	10 GHz PL Oscillator & Distributor																						
5.1.5	12 GHz PL Oscillator & Distributor																						
5.1.6	14 GHz PL Oscillator & Distributor																						
5.1.7	3.2-5.2 GHz Synthesizer																						
5.1.8	3.2 -5.2 GHz PLO and Fringe Generator																						
5.1.9	Sampler Clock 4 GHz PL Osc & Distributor																						
5.1.10	LO Ref Generator																						
5.1.11	LO Ref Distributor - Control Bldg																						
5.1.12	Microwave Round-trip Phase Measurement																						
5.1.13	10-15 GHz Frequency Synthesizer																						
5.1.14	First LO Fringe Generator																						
5.1.15	16 GHz PL Oscillator																						
5.1.16	26 GHz PL Oscillator																						
5.1.17	LO Ref Distributor - Antenna																						
5.1.18	VXCO Clean-up Loop																						
5.1.19	Power supply module																						
5.1.20	Bins / Racks (assemble and test)																						
5.3	Millimeter LO Drivers																						
5.3.1	Design and System Integration	3				\$	29								\$	4				\$	29		
5.3.2	72-95 GHz Source	6	8			\$	98	\$	180					\$	31	\$	59	\$	247	\$	59	\$	247
5.3.2.1	Contract Procurement and Fabrication																						
5.3.2.1.1	YIG-tuned Oscillator																						
5.3.2.1.2	18.00 - 23.75 GHz 10 db Amplifier																						
5.3.2.1.3	18.00 - 23.75 GHz x2 Multiplier																						
5.3.2.1.4	36.0 - 47.5 GHz 10 db Amplifier																						
5.3.2.1.5	36.0 - 47.5 GHz x2 Multiplier																						
5.3.2.1.6	Mount and Tuning circuitry																						
5.3.2.2	Assembly and Test																						
5.3.2.3	Deliver 72 - 95 GHz LO Sources																						
5.3.2.3.1	Deliver Modules #1-6																						
5.3.2.3.2	Deliver Modules #7-24																						
5.3.2.3.3	Deliver Modules #25-40																						
5.3.3	100-120 GHz Source	6	8			\$	98	\$	180					\$	278	\$	-	\$	-	\$	-	\$	-
5.3.3.1	Contract Procurement and Fabrication																						
5.3.3.1.1	YIG-tuned Oscillator																						
5.3.3.1.2	25.00 - 30.00 GHz 10 db Amplifier																						
5.3.3.1.3	15.00 - 30.00 GHz x2 Multiplier																						
5.3.3.1.4	50.0 - 60.0 GHz 10 db Amplifier																						
5.3.3.1.5	50-60 GHz x2 Multiplier																						
5.3.3.1.6	Mount and Tuning circuitry																						
5.3.3.2	Assembly and Test																						
5.3.3.3	Deliver 100 - 120 GHz LO Sources																						
5.3.3.3.1	Deliver Modules #1-3																						
5.3.3.3.2	Deliver Modules #4-21																						
5.3.3.3.3	Deliver Modules #22-40																						

5.3.4	87 - 108 GHz Source																		
5.3.4.1	Contract Procurement and Fabrication																		
5.3.4.1.1	YIG-tuned Oscillator																		
5.3.4.1.2	21.75-27.00 GHz 10 db Amplifier																		
5.3.4.1.3	21.75-27.00 GHz x2 Multiplier																		
5.3.4.1.4	43.5-54.0 GHz 10 db Amplifier																		
5.3.4.1.5	43.5-54.0 GHz x2 Multiplier																		
5.3.4.1.6	Mount and Tuning Circuitry																		
5.3.4.2	Assembly and Test																		
5.3.4.3	Deliver 87 - 108 GHz LO Sources																		
5.3.4.3.1	Deliver Modules #1-6																		
5.3.4.3.2	Deliver Modules #7-20																		
5.3.4.3.3	Deliver Modules #21-35																		
5.3.4.3.4	Deliver Modules #36-40																		
5.3.5	65 - 85 GHz Source																		
5.3.5.1	Contract Procurement and Fabrication																		
5.3.5.1.1	YIG-tuned Oscillator																		
5.3.5.1.2	16.25-21.25 GHz 10 db Amplifier																		
5.3.5.1.3	16.25-21.25 GHz x2 Multiplier																		
5.3.5.1.4	32.5-42.5 GHz 10 db Amplifier																		
5.3.5.1.5	32.5-42.5 GHz x2 Multiplier																		
5.3.5.1.6	Mount and Tuning Circuitry																		
5.3.5.2	Assembly and Test																		
5.3.5.3	Deliver 65 - 85 GHz LO Sources																		
5.3.5.3.1	Deliver Modules #1-6																		
5.3.5.3.2	Deliver Modules #7-20																		
5.3.5.3.3	Deliver Modules #21-35																		
5.3.5.3.4	Deliver Modules #36-40																		
5.4	Millimeter LO Multiplier Chains																		
5.4.1	Design and System Integration			24		24	\$	351	\$	250		\$	128	\$	601	\$	128	\$	601
5.4.2	211 - 275 GHz Receiver LO																		
5.4.2.1	Contract Fabrication																		
5.4.2.1.1	X3 Diode for 72-95 GHz Source																		
5.4.2.1.2	Machine Mount																		
5.4.2.1.3	Bias and Control circuits																		
5.4.2.2	Assemble Multiplier and Test																		
5.4.2.3	Integrate Source and Multiplier; test																		
5.4.2.4	Deliver 211-275 GHz Rcvr LO Modules																		
5.4.2.4.1	Deliver Modules #1-3																		
5.4.2.4.2	Deliver Modules #4-21																		
5.4.2.4.3	Deliver Modules #22-40																		
5.4.3	602 - 720 GHz Receiver LO																		
5.4.3.1	Contract Fabrication																		
5.4.3.1.1	X2 Diode for 100-120 GHz Source																		
5.4.3.1.2	X3 Diode for 200-240 GHz Input																		
5.4.3.1.3	Machine Mount																		
5.4.3.1.4	Bias and Control circuits																		
5.4.3.2	Assemble Multipliers and Test																		
5.4.3.3	Integrate Source and Multipliers; test																		

5.4.3.4	Deliver 602-720 GHz Rcvr LO Modules												
5.4.3.4.1	Deliver Modules #1-6												
5.4.3.4.2	Deliver Modules #7-18												
5.4.3.4.3	Deliver Modules #19-34												
5.4.3.4.4	Deliver Modules #35-40												
5.4.4	275 - 370 GHz Receiver LO												
5.4.4.1	Contract Fabrication												
5.4.4.1.1	X2 Diode for 72-95 GHz Source												
5.4.4.1.2	X2 Diode for 144-190 GHz Input												
5.4.4.1.3	Machine Mount												
5.4.4.1.4	Bias and Control Circuits												
5.4.4.2	Assemble Multipliers and Test												
5.4.4.3	Integrate Source and Multipliers; test												
5.4.4.4	Deliver 275-370 GHz Rcvr LO Modules												
5.4.4.4.1	Deliver Modules #1-6												
5.4.4.4.2	Deliver Modules #7-27												
5.4.4.4.3	Deliver Modules #28-40												
5.4.5	163 - 211 GHz Receiver LO												
5.4.5.1	Contract Fabrication												
5.4.5.1.1	X2 Diode for 87-108 GHz Source												
5.4.5.1.2	Machine Mount												
5.4.5.1.3	Bias and Control Circuits												
5.4.5.2	Assemble Multiplier and Test												
5.4.5.3	Integrate Source and Multiplier; test												
5.4.5.4	Deliver 163 - 211 GHz Rcvr LO Modules												
5.4.5.4.1	Deliver Modules #1-6												
5.4.5.4.2	Deliver Modules #7-24												
5.4.5.4.3	Deliver Modules #25-40												
5.4.6	385 - 500 GHz Receiver LO												
5.4.6.1	Contract Fabrication												
5.4.6.1.1	X3 Diode for 65-85 GHz Source												
5.4.6.1.2	X2 Diode for 130-170 GHz Input												
5.4.6.1.3	Machine Mount												
5.4.6.1.4	Bias and Control Circuits												
5.4.6.2	Assemble Multiplier and test												
5.4.6.3	Integrate source and Multiplier; test												
5.4.6.4	Deliver 385-500 GHz Rcvr LO Modules												
5.4.6.4.1	Deliver Modules #1-6												
5.4.6.4.2	Deliver Modules #7-24												
5.4.6.4.3	Deliver Modules #25-40												
5.4.7	125 - 163 GHz Receiver LO												
5.4.7.1	Contract Fabrication												
5.4.7.1.1	X2 Diode for 65 - 85 GHz Source												
5.4.7.1.2	Machine Mount												
5.4.7.1.3	Bias and Control Circuits												
5.4.7.2	Assemble Multiplier and test												
5.4.7.3	Integrate Source and Multiplier; test												
5.4.7.4	Deliver 125-163 GHz Rcvr LO Modules												
5.4.7.4.1	Deliver Modules #1-6												

5.4.7.4.2	Deliver Modules #7-18																		
5.4.7.4.3	Deliver Modules #19-34																		
5.4.7.4.4	Deliver Modules #35-40																		
5.4.8	33-45 GHz Receiver LO																		
5.4.8.1	Design & Fab Selection & Coupling from Sources			3	6	\$ 59	\$ 25				\$ 13	\$ 84	\$ 13	\$ 84					
6	IF System																		
6.1	IF System: Prototype Systems																		
6.1.1	Deliver (Bench) Prototype IF System																		
6.1.2	Testing and Design Refinement																		
6.1.3	Procure/Fab Field Prototypes																		
6.1.4	Deliver IF Field Prototypes to Test Interfeometer																		
6.1.5	Field Prototype testing and Design Refinement																		
6.1.6	Preproduction Review																		
6.1.7	Final Documentation and Design Modifications																		
6.1.8	Release for Manufacture																		
6.2	Production test and lab equipment			12	12	\$ 176	\$ 200				\$ 56	\$ 376	\$ 56	\$ 376					
6.3	IF Multiplexer																		
6.4	IF Demultiplexer																		
6.5	IF Matrix Switch																		
6.6	Baseband Converter																		
6.7	Power supply module																		
6.8	Bins / Racks (assemble and test)																		
7	Optical Fiber System																		
7.1	Optical Fiber System: Prototype Systems																		
7.1.1	Deliver (Bench) Prototype FO System																		
7.1.2	Testing and Design Refinement																		
7.1.3	Procure/Fab Field Prototypes																		
7.1.4	Deliver FO Field Prototypes to Test Interfeometer																		
7.1.5	Field Prototype testing and Design Refinement																		
7.1.6	Preproduction Review																		
7.1.7	Final Documentation and Design Modifications																		
7.1.8	Release for Manufacture																		
7.1	Production test and lab equipment			12	12	\$ 176	\$ 200				\$ 56	\$ 376	\$ 56	\$ 376					
7.2	IF TX / RX																		
7.3	LO Reference TX / RX																		
7.4	Microwave Round-trip Phase TX / RX																		
7.5	Monitor / Control TX / RX																		
7.6	Power supply module																		
7.7	Bins / Racks (assemble and test)																		
8	Correlator			36	36	\$ 527	\$ 2,000				\$ 281	\$ 337	\$ 2,246	\$ 337	\$ 2,246				
8.1	Digital Sampler, 4 GHz			12	12	\$ 176	\$ 428				\$ 67	\$ 80	\$ 536	\$ 80	\$ 536				
8.1.1	Refine Design																		
8.1.2	Release Digital Sampler for Manufacture																		
8.1.3	Contract Materials																		
8.1.4	Assembly																		
8.1.5	Validation and Delivery																		

8.2	Digital FIR Filter			24	24	\$ 351	\$ 533		\$ 67	\$ 123	\$ 817	\$ 123	\$ 817
8.2.1	Prototype testing on Test Interferometer												
8.2.2	Design Refinement												
8.2.3	Release FIR Filter for manufacture												
8.2.4	Chip Fabrication												
8.2.5	Assembly												
8.2.6	Validation and Delivery												
8.3	Custom Boards												
8.3.1	Correlator Board												
8.3.1.1	Prototype assembly												
8.3.1.2	Prototype test												
8.3.1.3	Design modifications												
8.3.1.4	Fab, assemble and test with design mods												
8.4	Correlator Chip												
8.4.1	Prototype chip fabrication												
8.4.2	Prototype chip test												
8.4.3	Design modifications												
8.4.4	Fabricate and test design mods												
8.4.5	Fabricate production run												
8.5	Racks												
8.5.1	Design control wiring												
8.5.2	Design signal wiring												
8.5.3	Order parts												
8.5.4	Assemble prototypes												
8.6	Software												
8.7	Prototype Correlator Production												
8.7.1	Order parts												
8.7.2	Assemble												
8.7.3	Test												
8.7.4	Deliver Prototype Correlator to VLA site												
8.8	Site Correlator Production												
8.8.1	First 1/4 correlator												
8.8.1.1	Determine configuration												
8.8.1.2	Order parts												
8.8.1.3	Assemble												
8.8.1.4	Test												
8.8.1.5	Deliver 1/4 Correlator to MMA site												
8.8.2	Second 1/4 correlator												
8.8.2.1	Order parts												
8.8.2.2	Assemble												
8.8.2.3	Test												
8.8.2.4	Deliver 1/4 Correlator to MMA site												
8.8.3	Third 1/4 correlator												
8.8.3.1	Order parts												
8.8.3.2	Assemble												
8.8.3.3	Test												
8.8.3.4	Deliver 1/4 Correlator to MMA site												
8.8.4	Fourth 1/4 correlator												
8.8.4.1	Order parts												
8.8.4.2	Assemble												
8.8.4.3	Test												

8.8.4.4	Deliver 1/4 Correlator to MMA site														
8.9	Continued Support														
9	Computing						\$ 50			\$ 15	\$ 50	\$ 15	\$ 50		
9.1	Control Software														
9.1.1	Test Interferometer Control & Analysis	33					\$ 286			\$ 43	\$ 286	\$ 43	\$ 286		
9.1.2	MMA correlator software	52					\$ 451			\$ 63	\$ 451	\$ 68	\$ 451		
9.1.3	Multi-antenna & sub-array control														
9.1.4	Operators & Observers interfaces	27					\$ 234			\$ 35	\$ 234	\$ 35	\$ 234		
9.1.5	Deliver Control Software														
9.1.6	Maintenance														
9.2	Scheduling														
9.2.1	Static scheduling system	10					\$ 87			\$ 13	\$ 87	\$ 13	\$ 87		
9.2.2	Dynamic scheduling simulations	24					\$ 208			\$ 31	\$ 208	\$ 31	\$ 208		
9.2.3	Dynamic scheduling prototype														
9.2.4	Dynamic scheduling implementation														
9.2.5	Initial Operations with Dynamic Scheduling														
9.3	Proposal Preparation Software														
9.3.1	Prototype	7					\$ 61			\$ 9	\$ 61	\$ 9	\$ 61		
9.3.2	Production version														
9.4	Image Pipeline														
9.4.1	Automated calibration & imaging heuristics	7					\$ 61			\$ 9	\$ 61	\$ 9	\$ 61		
9.4.2	Prototype image pipeline														
9.4.3	Parallelization studies and implementation														
9.4.4	Initial Image Pipeline Operations														
9.4.5	Production image pipeline														
9.5	Archiving														
9.5.1	Prototype distributed archive	10					\$ 87			\$ 13	\$ 87	\$ 13	\$ 87		
9.5.2	Evaluate storage hardware														
9.5.3	Production archive														
9.5.4	Data Archive operational														
9.6	Post-processing														
9.6.1	Define MMA Data formats														
9.6.2	MMA filler & format conversions														
9.6.3	MMA-specific calibrations														
9.6.4	MMA Post-processing begins														
9.6.5	Maintenance	6					\$ 52			\$ 8	\$ 52	\$ 8	\$ 52		
10	System Integration														
10.4	Test Interferometer Site Preparation							4	\$ 20	\$ 40		\$ 15	\$ 60	\$ 15	\$ 60
10.4.1	Complete Office and Lab Space Preparation														
10.4.2	Cabling														
10.4.3	Test Interferometer Site Complete														
10.10.4	Prototype Antenna Outfitting							18	\$ 88	\$ 50		\$ 28	\$ 138	\$ 28	\$ 138
10.10.4.1	Cabling														
10.10.4.2	Instrumentation														
10.10.4.3	Eval. Rcvr. #1 / Ant. #1 Integration														
10.10.4.4	Antenna #1 Outfitting Complete														
10.10.5	Integration Holography System/Antenna							2	\$ 10			\$ 1	\$ 10	\$ 1	\$ 10
10.10.6	Integration Metrology/Antenna							5	\$ 24			\$ 4	\$ 24	\$ 4	\$ 24
10.10.7	Antenna #1 Integration & Testing							7	\$ 34			\$ 5	\$ 34	\$ 5	\$ 34

10.10.8	Prot. Rcvr. Test & Evaluation																		
10.10.9	Antenna #2 Outfitting			21	\$	102	\$	50			\$	30	\$	152	\$	30	\$	152	
10.10.9.1	Cabling																		
10.10.9.2	Instrumentation																		
10.10.9.3	Eval. Rcvr. #2 / Ant. #2 Integration																		
10.10.9.4	Antenna #2 Outfitting Complete																		
10.11	Test Interferometer																		
10.11.1	Antenna Evaluation & Characterization																		
10.11.1.1	Antenna Verification																		
10.11.1.4	Holography																		
10.11.1.5	Beam and Sidelobes																		
10.11.1.6	Gain vs. Elevation: Spillover Temp																		
10.11.1.7	Effect of Sun in & Near the Beam																		
10.11.2	Engineering Recommendations re Prod. Ant.																		
10.11.3	Revise Interface Specifications																		
10.11.5	Operations Personnel Training																		
10.11.5.1	Recruit Initial Chile Ops Staff																		
10.11.5.2	Array Operations																		
10.11.5.3	Engineering Maintenance																		
10.11.5.4	Scientific Support & Analysis																		
10.12.2	Relocate Ops Staff to Chile																		
10.8.4.6	Start On-site Operations																		
10.12	Disassemble Test Interferometer																		
10.12.1	Prepare & Ship Antenna #1, #2																		
10.12.3	Restore Facilities at VLA Site																		
10.13	On Site System Integration																		
11	Calibration and Imaging																		
11.1	Radiometric Phase Design & Prototype		8		\$	78	\$	20			\$	18	\$	98	\$	18	\$	98	
11.1.1	Complete 183GHz Phase Mon Prototype																		
11.1.2	Demo 183 GHz Phase Monitor Radiometer on-Site																		
11.1.3	Design Refinement																		
11.1.4	Release Phase Mon Radiometer for manufacture																		
11.2	Production Fab of Phase Monitor Radiometer						\$	170		\$	19	\$	45	\$	151	\$	45	\$	151
11.2.1	Contract Subassembly Fabrication																		
11.2.1.1	Radiometer & Local Oscillator																		
11.2.1.2	Spectrometer																		
11.2.1.3	Feed, Window, lens, instrumentation																		
11.2.1.4	M/C Interface																		
11.2.2	Assembly & Test																		
11.2.3	Deliver Production Radiometers																		
11.2.4	Integration in Receiver Package																		
11.2.5	Verification on-Site																		
11.3	Production Fabrication of Dual-load Amp Cal Sys																		
11.3.1	Design Refinement																		
11.3.2	Release Phase Mon Radiometer for manufacture																		
11.3.3	Contract Subassembly																		
11.3.3.1	Machining																		
11.3.3.2	Load Fabrication																		
11.3.3.3	Motors, Servo																		
11.3.3.4	M/C Interface																		
11.3.4	Assembly & Test																		

11.3.5	Integration on Production Antennas												
11.4	Imaging Studies & Project Support	48				\$ 390				\$ 59	\$ 390	\$ 59	\$ 390
11.5	Imaging Algorithm Development	8	4			\$ 100				\$ 15	\$ 100	\$ 15	\$ 100
TOTALS						\$ 7,928	\$ 9,568	\$ -	\$ 1,976	\$ 2,509	\$ 15,520	\$ 2,509	\$ 15,520

Millimeter Array Construction 2002

WBS	Name	Scientists Work- Months	Programmers Work-Months	Engineers Work- Months	Technicians Work- Months	Personnel Cost	Materials and Supplies	Transfer to Operations	Adjustment to Scope	Contingency	Sum Cost	Inflated Contingency	Inflated Sum
1	Administration												
1.1	Project Management	72			24	\$ 702		\$ 98		\$ 91	\$ 605	\$ 93	\$ 620
1.1.1	Management, Planning, and Oversight						\$ 600			\$ -	\$ 600	\$ -	\$ 615
1.1.2	Business Operations						\$ 50			\$ 8	\$ 50	\$ 8	\$ 51
1.1.3	Chilean Operations						\$ 50			\$ 8	\$ 50	\$ 8	\$ 51
1.1.4	Safety and Health												
1.1.5	Personnel												
1.1.6	Project Science Office												
1.1.7	AUI Management						\$ 350			\$ -	\$ 350	\$ -	\$ 359
1.2	Engineering			24	12	\$ 293	\$ 20			\$ 47	\$ 313	\$ 48	\$ 320
1.2.1	System Engineering--Phase II												
1.2.2	Documentation System												
1.2.3	Production Engineering												
1.3	US Facilities												
1.3.1	CDL Permanent Facilities						\$ 600			\$ -	\$ 600	\$ -	\$ 615
1.3.2	Manufacturing Facilities						\$ 100			\$ 15	\$ 100	\$ 15	\$ 103
1.3.3	Common Infrastructure						\$ 200			\$ 30	\$ 200	\$ 31	\$ 205
2	Site Development			12		\$ 117	\$ 50			\$ 28	\$ 167	\$ 28	\$ 171
2.1	Review Legalities Regarding Array and OSF Sites												
2.2	Maintain Mining claims						\$ 25			\$ -	\$ 25	\$ -	\$ 26
2.3	Contract A&E Studies												
2.4	Hire Construction Manager for Chile												
2.5	Array Site												
2.5.1	Prepare Site Development Bid Packages												
2.5.1.1	Prepare Package for Array Site												
2.5.1.2	Review Bid Packages												
2.5.1.3	Bid Civil Works Construction												
2.5.2	Evaluate Array Site Bid Response												
2.5.2.1	Review Bids												
2.5.2.2	Recommend Contractors												
2.5.2.3	Award Array Site Contracts												
2.5.3	Contract Array Site Civil Works						\$ 17,507		\$ 2,153	\$ 3,071	\$ 15,355	\$ 3,148	\$ 15,738
2.5.3.1	Array Site												
2.5.3.2	Inspect Completed Site Constr												
2.5.3.3	Accept Site Facility												
2.6	Operations Support Facility												
2.6.1	Prepare OSF Bid Packages												
2.6.1.1	Prepare Package for OSF												
2.6.1.2	Review Bid Packages												
2.6.1.3	Bid Civil Works Construction												
2.6.2	Evaluate OSF Bid Response												
2.6.2.1	Review Bids												
2.6.2.2	Recommend Contractors												
2.6.2.3	Award Contracts												

2.6.3	Contract OSF Civil Works					\$ 10,637	\$ 503	\$ 644	\$ 1,923	\$ 9,491	\$ 1,971	\$ 9,728
2.6.3.1	Operations Support Facility											
2.6.3.2	Inspect Completed OSF Constr											
2.6.3.3	Accept OSF Facility											
2.7	OSF/Array Link											
2.7.1	Prepare OSF/Array Link Bid Package											
2.7.1.1	Prepare Package for OSF/Array F/O Link											
2.7.1.2	Review Bid Package											
2.7.1.3	Bid OSF/Array Link Construction											
2.7.2	Evaluate Bid Response											
2.7.2.1	Review Bids											
2.7.2.2	Recommend Contractors											
2.7.2.3	Award Contracts											
2.7.3	Contract Civil Works					\$ 3,890			\$ 778	\$ 3,890	\$ 797	\$ 3,987
2.7.3.1	OSF/Array Link											
2.7.3.2	Inspect Completed OSF/Array Link Constr											
2.7.3.3	Accept OSF/Array Link											
2.8	Prepare for Instrument Assembly											
2.8.1	Equip Array Site					\$ 5,430			\$ 1,086	\$ 5,430	\$ 1,113	\$ 5,566
2.8.2	Equip Operations Support Facility											
3	Antenna											
3.1	Antenna Engineering Support		48			\$ 468			\$ 70	\$ 468	\$ 72	\$ 480
3.3.40	Acceptance Tests Antenna #1											
3.3.45	Delivery of Antenna #1											
3.8.10	Sign Transporter Contract											
3.8.15	Transporter Acceptance tests											
3.8.20	Deliver/Accept Transporter #1											
3.7	Procurement of Antenna #2											
3.7.1	Antenna #2 Contract Supervision											
3.7.2	Antenna #2 Acceptance tests											
3.8	Negotiate Production Antenna Contract											
3.9	Sign Contract for Production Antennas											
3.10	Antenna Contract Supervision											
3.11	Accept Antenna #3 at OSF											
3.12	Prepare Antenna #3											
3.12.1	Outfit & Verify Ant #3 at OSF											
3.12.2	Move, Install & Verify Ant #3 on Site											
3.13	Accept Antenna #4 at OSF											
3.14	Prepare Antenna #4											
3.14.1	Outfit & Verify Ant #4 at OSF											
3.14.2	Move, Install & Verify Ant #4 on Site											
3.15	Accept Antenna#5 at OSF											
3.16	Prepare Antenna #5											
3.16.1	Outfit & Verify Ant #5 at OSF											
3.16.2	Move, Install & Verify Ant #5 on Site											
3.17	Accept Antenna#6 at OSF											
3.18	Prepare Antenna #6											
3.18.1	Outfit & Verify Ant #6 at OSF											
3.18.2	Move, Install & Verify Ant #6 on Site											

3.19	Accept Antenna #7 at OSF												
3.20	Prepare Antenna #7												
3.20.1	Outfit & Verify Ant #7 at OSF												
3.20.2	Move, Install & Verify Ant #7 on Site												
3.21	Accept Antenna #8 at OSF												
3.22	Prepare Antenna #8												
3.22.1	Outfit & Verify Ant #8 at OSF												
3.22.2	Move, Install & Verify Ant #8 on Site												
3.23	Accept Antenna #9 at OSF												
3.24	Prepare Antenna #9												
3.24.1	Outfit & Verify Ant #9 at OSF												
3.24.2	Move, Install & Verify Ant #9 on Site												
3.25	Accept Antenna #10 at OSF												
3.26	Prepare Antenna #10												
3.26.1	Outfit & Verify Ant #10 at OSF												
3.26.2	Move, Install and Verify Ant #10 on Site												
3.27	Accept Antenna #11 at OSF												
3.28	Prepare Antenna #11												
3.28.1	Outfit & Verify Ant #11 at OSF												
3.28.2	Move, Install & Verify Ant #11 on Site												
3.29	Accept Antenna #12 at OSF												
3.30	Prepare Antenna #12												
3.30.1	Outfit & Verify Ant #12 at OSF												
3.30.2	Move, Install & Verify Ant #12 on Site												
3.31	Accept Antenna #13 at OSF												
3.32	Prepare Antenna #13												
3.32.1	Outfit & Verify Ant #13 at OSF												
3.32.2	Move, Install & Verify Ant #13 on Site												
3.33	Accept Antenna #14 at OSF												
3.34	Prepare Antenna #14												
3.34.1	Outfit & Verify Ant #14 at OSF												
3.34.2	Move, Install & Verify Ant #14 on Site												
3.35	Accept Antenna #15 at OSF												
3.36	Prepare Antenna #15												
3.36.1	Outfit & Verify Ant #15 at OSF												
3.36.2	Move, Install & Verify Ant #15 on Site												
3.37	Accept Antenna #16 at OSF												
3.38	Prepare Antenna #16												
3.38.1	Outfit & Verify Ant #16 at OSF												
3.38.2	Move, Install & Verify Ant #16 on Site												
3.39	Accept Antenna #17 at OSF												
3.40	Prepare Antenna #17												
3.40.1	Outfit & Verify Ant #17 at OSF												
3.40.2	Move, Install & Verify Ant #17 on Site												
3.41	Accept Antenna #18 at OSF												
3.42	Prepare Antenna #18												
3.42.1	Outfit & Verify Ant #18 at OSF												
3.42.2	Move, Install & Verify Ant #18 on Site												
3.43	Accept Antenna #19 at OSF												
3.44	Prepare Antenna #19												
3.44.1	Outfit & Verify Ant #19 at OSF												
3.44.2	Move, Install & Verify Ant #19 on Site												
3.45	Accept Antenna #20 at OSF												

3.46	Prepare Antenna #20																			
3.46.1	Outfit & Verify Ant #20 at OSF																			
3.46.2	Move, Install & Verify Ant #20 on Site																			
3.47	Accept Antenna #21 at OSF																			
3.48	Prepare Antenna #21																			
3.48.1	Outfit & Verify Ant #21 at OSF																			
3.48.2	Move, Install & Verify Ant #21 on Site																			
3.49	Accept Antenna #22 at OSF																			
3.50	Prepare Antenna #22																			
3.50.1	Outfit & Verify Ant #22 at OSF																			
3.50.2	Move, Install & Verify Ant #22 on Site																			
3.51	Accept Antenna #23 at OSF																			
3.52	Prepare Antenna #23																			
3.52.1	Outfit & Verify Ant #23 at OSF																			
3.52.2	Move, Install & Verify Ant #23 on Site																			
3.53	Accept Antenna #24 at OSF																			
3.54	Prepare Antenna #24																			
3.54.1	Outfit & Verify Ant #24 at OSF																			
3.54.2	Move, Install & Verify Ant #24 on Site																			
3.55	Accept Antenna #25 at OSF																			
3.56	Prepare Antenna #25																			
3.56.1	Outfit & Verify Ant #25 at OSF																			
3.56.2	Move, Install & Verify Ant #25 on Site																			
3.57	Accept Antenna #26 at OSF																			
3.58	Prepare Antenna #26																			
3.58.1	Outfit & Verify Ant #26 at OSF																			
3.58.2	Move, Install & Verify Ant #26 on Site																			
3.59	Accept Antenna #27 at OSF																			
3.60	Prepare Antenna #27																			
3.60.1	Outfit & Verify Ant #27 at OSF																			
3.60.2	Move, Install & Verify Ant #27 on Site																			
3.61	Accept Antenna #28 at OSF																			
3.62	Prepare Antenna #28																			
3.62.1	Outfit & Verify Ant #28 at OSF																			
3.62.2	Move, Install & Verify Ant #28 on Site																			
3.63	Accept Antenna #29 at OSF																			
3.64	Prepare Antenna #29																			
3.64.1	Outfit & Verify Ant #29 at OSF																			
3.64.2	Move, Install & Verify Ant #29 on Site																			
3.65	Accept Antenna #30 at OSF																			
3.66	Prepare Antenna #30																			
3.66.1	Outfit & Verify Ant #30 at OSF																			
3.66.2	Move, Install & Verify Ant #30 on Site																			
3.67	Accept Antenna #31 at OSF																			
3.68	Prepare Antenna #31																			
3.68.1	Outfit & Verify Ant #31 at OSF																			
3.68.2	Move, Install and Verify Ant #31 on Site																			
3.69	Accept Antenna #32 at OSF																			
3.70	Prepare Antenna #32																			
3.70.1	Outfit & Verify Ant #32 at OSF																			
3.70.2	Move, Install & Verify Ant #32 on Site																			
3.71	Accept Antenna #33 at OSF																			
3.72	Prepare Antenna #33																			

3.72.1	Outfit & Verify Ant #33 at OSF																						
3.72.2	Move, Install and Verify Ant #33 on Site																						
3.73	Accept Antenna #34 at OSF																						
3.74	Prepare Antenna #34																						
3.74.1	Outfit & Verify Ant #34 at OSF																						
3.74.2	Move, Install and Verify Ant #34 on Site																						
3.75	Accept Antenna #35 at OSF																						
3.76	Prepare Antenna #35																						
3.76.1	Outfit & Verify Ant #35 at OSF																						
3.76.2	Move, Install & Verify Ant #35 on Site																						
3.77	Accept Antenna #36 at OSF																						
3.78	Prepare Antenna #36																						
3.78.1	Outfit & Verify Ant #36 at OSF																						
3.78.2	Move, Install & Verify Ant #36 on Site																						
3.79	Prepare Antenna #1																						
3.79.1	Antenna #1 Reassembled at OSF																						
3.79.2	Outfit & Verify Ant #1 at OSF																						
3.79.3	Move, Install & Verify Ant #1 on Site																						
3.80	Prepare Antenna #2																						
3.80.1	Antenna #2 Reassembled at OSF																						
3.80.2	Outfit & Verify Ant #2 at OSF																						
3.80.3	Move, Install & Verify Ant #2 on Site																						
3.81	Antenna Transporter																						
3.81.1	Contract for Transporter #1, move to Site																						
3.81.2	Contract for Transporters #2, #3																						
3.81.3	Accept Transporters #2, #3 at OSF																						
4	Receivers																						
4.1	Receiver Package																						
4.1.1	Prototype Production Receiver Cryogenics																						
4.1.1.1	CDR: Cryogenics Development																						
4.1.1.2	Construct & test prototype cryogenics																						
4.1.1.3	Deliver Prototype Cryogenics Subsystem																						
4.1.2	Prototype Production Receiver Package		12		12	\$	176	\$	100					\$	56	\$	276	\$	58	\$	282		
4.1.2.1	Prototype Receiver Package Integration																						
4.1.2.2	Prot. Rcvr. Pckg Lab Test & Evaluation																						
4.1.2.3	Complete Prototype MMA Receiver Package																						
4.1.3	MMA Rcvr Pckg Design Refinement																						
4.1.4	Documentation																						
4.1.5	Release MMA Receiver Pckg for manufacture																						
4.1.6	Contract for Receiver Pckg Subassemblies																						
4.1.6.1	Machine Dewars					30	\$	146	\$	50				\$	22	\$	30	\$	174	\$	31	\$	179
4.1.6.2	Fabricate Cryogenics subsystems		6		24	\$	176	\$	240					\$	46	\$	84	\$	369	\$	87	\$	379
4.1.6.3	Fabricate windows, IR filters, etc		6		30	\$	205	\$	100					\$	34	\$	51	\$	271	\$	52	\$	278
4.1.7	Accept Receiver Pckg Subassemblies																						
4.1.7.1	Subassemblies #1-6																						
4.1.7.2	Subassemblies #7-16																						
4.1.7.3	Subassemblies #17-26																						
4.1.7.4	Subassemblies #27-36																						
4.1.7.5	Subassemblies #37-40																						

4.1.8	Fab Rcvr Pckg Instrumentation & Electronics		12	12	12	\$ 280	\$ 100		\$ 42	\$ 59	\$ 337	\$ 61	\$ 346
4.1.9	Fabricate Receiver Inserts			24	24	\$ 351	\$ 100		\$ 50	\$ 68	\$ 401	\$ 69	\$ 411
4.1.10	Assemble Receiver Package												
4.1.10.1	Integrate Rcvr Instrumentation & subass'y			24	36	\$ 410	\$ 80		\$ 54	\$ 69	\$ 435	\$ 71	\$ 446
4.1.10.2	Deliver Receiver Package #1-6												
4.1.10.3	Deliver Receiver Package #7-16												
4.1.10.4	Deliver Receiver Package #17-26												
4.1.10.5	Deliver Receiver Package #27-36												
4.1.10.6	Deliver Receiver Package #37-40												
4.2	SIS Receiver Modules												
4.2.1	211-275 GHz Module			36	24	\$ 468	\$ 100		\$ 63	\$ 81	\$ 505	\$ 83	\$ 518
4.2.1.1	SIS Mixer												
4.2.1.1.1	Design, Fab and Test Mixer Design												
4.2.1.1.2	Deliver Production Design												
4.2.1.1.3	Fabricate Production Mixers												
4.2.1.2	Design & Verify Optics												
4.2.1.3	Design Module												
4.2.1.4	Contract Fabrication				4	\$ 20	\$ 100		\$ 13	\$ 29	\$ 106	\$ 30	\$ 109
4.2.1.4.1	Machine Mixer Blocks, Feed, WG, Lenses												
4.2.1.4.2	Assemble Modules												
4.2.1.5	Install SIS Mixer & Test Modules			12	24	\$ 234	\$ 40		\$ 30	\$ 38	\$ 244	\$ 39	\$ 250
4.2.1.6	Deliver 211-275 GHz Receiver Modules												
4.2.1.6.1	Deliver Modules #1-7												
4.2.1.6.2	Deliver Modules #8-26												
4.2.1.6.3	Deliver Modules #27-40												
4.2.2	602-720 GHz Module			36	24	\$ 468	\$ 100		\$ 568	\$ -	\$ -	\$ -	\$ -
4.2.2.1	SIS Mixer								\$ -	\$ -	\$ -	\$ -	\$ -
4.2.2.1.1	Design, Fabricate and Test Mixer Design								\$ -	\$ -	\$ -	\$ -	\$ -
4.2.2.1.2	Deliver Production Design								\$ -	\$ -	\$ -	\$ -	\$ -
4.2.2.1.3	Fabricate Production Mixers								\$ -	\$ -	\$ -	\$ -	\$ -
4.2.2.2	Design & Verify Optics												
4.2.2.3	Design Module												
4.2.2.4	Contract Fabrication				4	\$ 20	\$ 100		\$ 120	\$ -	\$ -	\$ -	\$ -
4.2.2.4.1	Machine Mixer Blocks, Feed, WG, Lenses												
4.2.2.4.2	Assemble Modules												
4.2.2.5	Install SIS Mixer and Test Modules			12	24	\$ 234	\$ 40		\$ 274	\$ -	\$ -	\$ -	\$ -
4.2.2.6	Deliver 602-720 GHz Receiver Modules												
4.2.2.6.1	Deliver Modules #1-7												
4.2.2.6.2	Deliver Modules #8-26												
4.2.2.6.3	Deliver Modules #27-40												
4.2.3	275-370 GHz Receiver Module			24	24	\$ 351	\$ 400		\$ 83	\$ 148	\$ 668	\$ 151	\$ 684
4.2.3.1	SIS Mixer												
4.2.3.1.1	Design, Fabricate and Test Mixer Design												
4.2.3.1.2	Deliver Production Design												
4.2.3.1.3	Fabricate Production Mixers												
4.2.3.2	Design & Verify Optics			2		\$ 20			\$ 2	\$ 2	\$ 17	\$ 2	\$ 18
4.2.3.3	Design Module			6		\$ 59	\$ 50		\$ 12	\$ 20	\$ 96	\$ 21	\$ 99
4.2.3.4	Contract Fabrication				2	\$ 10	\$ 50		\$ 7	\$ 14	\$ 53	\$ 15	\$ 54
4.2.3.4.1	Machine Mixer Blocks, Feed, WG, Lenses												
4.2.3.4.2	Assemble Modules												

4.2.3.5	Install SIS Mixer and Test Modules																				
4.2.3.6	Deliver 275-370 GHz Receiver Module																				
4.2.3.6.1	Deliver Modules #1-5																				
4.2.3.6.2	Deliver Modules #6-30																				
4.2.3.6.3	Deliver Modules #30-40																				
4.2.4	91-119 GHz Receiver Module		24	24	\$	351	\$	400			\$	83	\$	148	\$	668	\$	151	\$	329	
4.2.4.1	SIS Mixer										\$	-	\$	-	\$	-	\$	-	\$	-	
4.2.4.1.1	Design, Fabricate & Test Mixer Design										\$	-	\$	-	\$	-	\$	-	\$	-	
4.2.4.1.2	Deliver Production Design										\$	-	\$	-	\$	-	\$	-	\$	-	
4.2.4.1.3	Fabricate Production Mixers																				
4.2.4.2	Design & Verify Optics		2			\$	20				\$	2	\$	2	\$	17	\$	2	\$	18	
4.2.4.3	Design Module		6			\$	59	\$	50		\$	12	\$	20	\$	96	\$	21	\$	99	
4.2.4.4	Contract Fabrication			2		\$	10	\$	50		\$	7	\$	14	\$	53	\$	15	\$	54	
4.2.4.4.1	Machine Mixer Blocks, Feed, WG, Lenses																				
4.2.4.4.2	Assemble Modules																				
4.2.4.5	Install SIS Mixer and Test Modules																				
4.2.4.6	Deliver 91-119 GHz Receiver Modules																				
4.2.4.6.1	Deliver Modules #1-5																				
4.2.4.6.2	Deliver Modules #6-30																				
4.2.4.6.3	Deliver Modules # 31-40																				
4.2.5	163-211 GHz Receiver Module																				
4.2.5.1	SIS Mixer																				
4.2.5.1.1	Design, Fabricate & Test Mixer Design																				
4.2.5.1.2	Deliver Production Design																				
4.2.5.1.3	Fabricate Production Mixers																				
4.2.5.2	Design & Verify Optics		6			\$	59	\$	50		\$	12	\$	20	\$	96	\$	21	\$	99	
4.2.5.3	Design Module		6			\$	59	\$	50		\$	12	\$	20	\$	96	\$	21	\$	99	
4.2.5.4	Contract Fabrication																				
4.2.5.4.1	Machine Mixer Blocks, Feed, WG, Lenses																				
4.2.5.4.2	Assemble Modules																				
4.2.5.5	Install SIS Mixer and Test																				
4.2.5.6	Deliver 163-211 GHz Receiver Modules																				
4.2.5.6.1	Deliver Modules #1-5																				
4.2.5.6.2	Deliver Modules #6-30																				
4.2.5.6.3	Deliver Modules #31-40																				
4.2.6	385-500 GHz Receiver Module																				
4.2.6.1	SIS Mixer																				
4.2.6.1.1	Design, Fabricate & Test Mixer Design																				
4.2.6.1.2	Deliver Production Design																				
4.2.6.1.3	Fabricate Production Mixers																				
4.2.6.2	Design and Verify Optics		6			\$	59	\$	50		\$	109	\$	-	\$	-	\$	-	\$	-	
4.2.6.3	Design Module		6			\$	59	\$	50		\$	109	\$	-	\$	-	\$	-	\$	-	
4.2.6.4	Contract Fabrication																				
4.2.6.4.1	Machine Mixer Blocks, Feed, WG, Lenses																				
4.2.6.4.2	Assemble Modules																				
4.2.6.5	Install SIS Mixer and Test																				
4.2.6.6	Deliver 385-500 GHz Receiver Modules																				
4.2.6.6.1	Deliver Modules #1-5																				
4.2.6.6.2	Deliver Modules #6-30																				
4.2.6.6.3	Deliver Modules #31-40																				

4.2.7	125-163 GHz Receiver Module																		
4.2.7.1	SIS Mixer																		
4.2.7.1.1	Design, Fabricate & Test Mixer Design																		
4.2.7.1.2	Deliver Production Design																		
4.2.7.1.3	Fabricate Production Mixers																		
4.2.7.2	Design & Verify Optics																		
4.2.7.3	Design Module																		
4.2.7.4	Contract Fabrication																		
4.2.7.4.1	Machine Mixer Blocks, Feed, WG, Lenses																		
4.2.7.4.2	Assemble Modules																		
4.2.7.5	Install SIS Mixer and Test																		
4.2.7.6	Deliver 125-163 GHz Receiver Modules																		
4.2.7.6.1	Deliver 125-163 GHz Modules #1-5																		
4.2.7.6.2	Deliver 125-163 GHz Modules #6-30																		
4.2.7.6.3	Deliver 125-163 GHz Modules #31-40																		
4.3	HFET Receiver Modules	7	15	\$	141	\$	70	\$	23	\$	28	\$	188	\$	29	\$	193		
4.3.1	Contract for HFET Wafer																		
4.3.2	Receive Diced HFET Wafer																		
4.3.3	33-45 GHz Module																		
4.3.3.1	Design Module																		
4.3.3.2	Design & Verify Optics																		
4.3.3.3	Contract Fabrication																		
4.3.3.3.1	Machine Blocks, Feed, WG, Lenses																		
4.3.3.3.2	Assemble Modules																		
4.3.3.3.3	Flip-in Mirror																		
4.3.4	Install HFET & Test Modules																		
4.3.5	Deliver 33-45 GHz Receiver Modules																		
4.3.5.1	Deliver Modules #1-20																		
4.3.5.2	Deliver Modules #21-40																		
4.3.6	67-95 GHz Module																		
4.3.6.1	Design Amplifier																		
4.3.6.2	Design Module																		
4.3.6.3	Design & Verify Optics																		
4.3.6.4	Contract Fabrication																		
4.3.6.4.1	Machine Blocks, Feed, WG, Lenses																		
4.3.6.4.2	Assemble Modules																		
4.3.6.5	Install HFET & Test Modules																		
4.3.6.6	Deliver 67-95 GHz Receiver Modules																		
4.3.6.6.1	Deliver Modules 67-95GHz #1-20																		
4.3.6.6.2	Deliver Modules 67-95GHz #21-40																		
5	LO System																		
5.1	LO Reference: Prototype Systems																		
5.1.1	Deliver: Bench Prototype																		
5.1.2	Testing and Design Refinement																		
5.1.3	Procure/Fab Field Prototypes																		
5.1.4	Deliver: LO Ref Field Prototypes																		
5.1.5	Field Prototype testing and Design Refinement																		
5.1.6	Preproduction Review																		

5.1.7	Final Documentation and Design Modifications																	
5.1.8	Release for Manufacture																	
5.2	LO Reference: Production System	12	12	\$	176			\$	26	\$	176	\$	27	\$	180			
5.1.1	Production test and lab equipment																	
5.1.2	H-maser Frequency Standard (& Rb)																	
5.1.3	8 GHz PL Oscillator & Distributor						\$	3	\$	0	\$	1	\$	3	\$	1	\$	3
5.1.4	10 GHz PL Oscillator & Distributor						\$	5	\$	1	\$	1	\$	4	\$	1	\$	5
5.1.5	12 GHz PL Oscillator & Distributor						\$	5	\$	1	\$	1	\$	4	\$	1	\$	5
5.1.6	14 GHz PL Oscillator & Distributor						\$	5	\$	1	\$	1	\$	4	\$	1	\$	5
5.1.7	3.2-5.2 GHz Synthesizer						\$	40	\$	4	\$	11	\$	36	\$	11	\$	36
5.1.8	3.2 -5.2 GHz PLO and Fringe Generator						\$	800	\$	89	\$	213	\$	711	\$	219	\$	729
5.1.9	Sampler Clock 4 GHz PL Osc & Distributor						\$	3	\$	0	\$	1	\$	3	\$	1	\$	3
5.1.10	LO Ref Generator						\$	8	\$	1	\$	2	\$	7	\$	2	\$	7
5.1.11	LO Ref Distributor - Control Bldg						\$	3	\$	0	\$	1	\$	3	\$	1	\$	3
5.1.12	Microwave Round-trip Phase Measurement						\$	300	\$	33	\$	80	\$	267	\$	82	\$	273
5.1.13	10-15 GHz Frequency Synthesizer						\$	500	\$	56	\$	133	\$	444	\$	137	\$	456
5.1.14	First LO Fringe Generator						\$	100	\$	11	\$	27	\$	89	\$	27	\$	91
5.1.15	16 GHz PL Oscillator						\$	200	\$	22	\$	53	\$	178	\$	55	\$	182
5.1.16	26 GHz PL Oscillator						\$	200	\$	22	\$	53	\$	178	\$	55	\$	182
5.1.17	LO Ref Distributor - Antenna						\$	100	\$	11	\$	27	\$	89	\$	27	\$	91
5.1.18	VXCO Clean-up Loop						\$	100	\$	11	\$	27	\$	89	\$	27	\$	91
5.1.19	Power supply module						\$	300	\$	33	\$	80	\$	267	\$	82	\$	273
5.1.20	Bins / Racks (assemble and test)						\$	80	\$	9	\$	21	\$	71	\$	22	\$	73
5.3	Millimeter LO Drivers																	
5.3.1	Design and System Integration	3		\$	29					\$	4	\$	29	\$	4	\$	30	
5.3.2	72-95 GHz Source	6	8	\$	98	\$	240		\$	38	\$	75	\$	300	\$	77	\$	308
5.3.2.1	Contract Procurement and Fabrication																	
5.3.2.1.1	YIG-tuned Oscillator																	
5.3.2.1.2	18.00 - 23.75 GHz 10 db Amplifier																	
5.3.2.1.3	18.00 - 23.75 GHz x2 Multiplier																	
5.3.2.1.4	36.0 - 47.5 GHz 10 db Amplifier																	
5.3.2.1.5	36.0 - 47.5 GHz x2 Multiplier																	
5.3.2.1.6	Mount and Tuning circuitry																	
5.3.2.2	Assembly and Test																	
5.3.2.3	Deliver 72 - 95 GHz LO Sources																	
5.3.2.3.1	Deliver Modules #1-6																	
5.3.2.3.2	Deliver Modules #7-24																	
5.3.2.3.3	Deliver Modules #25-40																	
5.3.3	100-120 GHz Source	6	8	\$	98	\$	240		\$	338	\$	-	\$	-	\$	-	\$	-
5.3.3.1	Contract Procurement and Fabrication																	
5.3.3.1.1	YIG-tuned Oscillator																	
5.3.3.1.2	25.00 - 30.00 GHz 10 db Amplifier																	
5.3.3.1.3	15.00 - 30.00 GHz x2 Multiplier																	
5.3.3.1.4	50.0 - 60.0 GHz 10 db Amplifier																	
5.3.3.1.5	50-60 GHz x2 Multiplier																	
5.3.3.1.6	Mount and Tuning circuitry																	
5.3.3.2	Assembly and Test																	
5.3.3.3	Deliver 100 - 120 GHz LO Sources																	
5.3.3.3.1	Deliver Modules #1-3																	
5.3.3.3.2	Deliver Modules #4-21																	
5.3.3.3.3	Deliver Modules #22-40																	

5.4.3.4	Deliver 602-720 GHz Rcvr LO Modules																			
5.4.3.4.1	Deliver Modules #1-6																			
5.4.3.4.2	Deliver Modules #7-18																			
5.4.3.4.3	Deliver Modules #19-34																			
5.4.3.4.4	Deliver Modules #35-40																			
5.4.4	275 - 370 GHz Receiver LO		3	9	\$	73	\$	20		\$	10	\$	14	\$	83	\$	14	\$	85	
5.4.4.1	Contract Fabrication																			
5.4.4.1.1	X2 Diode for 72-95 GHz Source																			
5.4.4.1.2	X2 Diode for 144-190 GHz Input																			
5.4.4.1.3	Machine Mount																			
5.4.4.1.4	Bias and Control Circuits																			
5.4.4.2	Assemble Multipliers and Test																			
5.4.4.3	Integrate Source and Multipliers; test																			
5.4.4.4	Deliver 275-370 GHz Rcvr LO Modules																			
5.4.4.4.1	Deliver Modules #1-6																			
5.4.4.4.2	Deliver Modules #7-27																			
5.4.4.4.3	Deliver Modules #28-40																			
5.4.5	163 - 211 GHz Receiver LO		3	9	\$	73	\$	20		\$	10	\$	14	\$	83	\$	14	\$	85	
5.4.5.1	Contract Fabrication																			
5.4.5.1.1	X2 Diode for 87-108 GHz Source																			
5.4.5.1.2	Machine Mount																			
5.4.5.1.3	Bias and Control Circuits																			
5.4.5.2	Assemble Multiplier and Test																			
5.4.5.3	Integrate Source and Multiplier; test																			
5.4.5.4	Deliver 163 - 211 GHz Rcvr LO Modules																			
5.4.5.4.1	Deliver Modules #1-6																			
5.4.5.4.2	Deliver Modules #7-24																			
5.4.5.4.3	Deliver Modules #25-40																			
5.4.6	385 - 500 GHz Receiver LO																			
5.4.6.1	Contract Fabrication																			
5.4.6.1.1	X3 Diode for 65-85 GHz Source																			
5.4.6.1.2	X2 Diode for 130-170 GHz Input																			
5.4.6.1.3	Machine Mount																			
5.4.6.1.4	Bias and Control Circuits																			
5.4.6.2	Assemble Multiplier and test																			
5.4.6.3	Integrate source and Multiplier; test																			
5.4.6.4	Deliver 385-500 GHz Rcvr LO Modules																			
5.4.6.4.1	Deliver Modules #1-6																			
5.4.6.4.2	Deliver Modules #7-24																			
5.4.6.4.3	Deliver Modules #25-40																			
5.4.7	125 - 163 GHz Receiver LO																			
5.4.7.1	Contract Fabrication																			
5.4.7.1.1	X2 Diode for 65 - 85 GHz Source																			
5.4.7.1.2	Machine Mount																			
5.4.7.1.3	Bias and Control Circuits																			
5.4.7.2	Assemble Multiplier and test																			
5.4.7.3	Integrate Source and Multiplier; test																			
5.4.7.4	Deliver 125-163 GHz Rcvr LO Modules																			
5.4.7.4.1	Deliver Modules #1-6																			

5.4.7.4.1
Deliver Modules #1-6

5.4.7.4.2	Deliver Modules #7-18																	
5.4.7.4.3	Deliver Modules #19-34																	
5.4.7.4.4	Deliver Modules #35-40																	
5.4.8	33-45 GHz Receiver LO	3	6	\$	59	\$	25		\$	9	\$	13	\$	74	\$	14	\$	76
5.4.8.1	Design & Fab Selection & Coupling from Sources																	
6	IF System	12	12	\$	176				\$	26	\$	176	\$	27	\$	180		
6.1	IF System: Prototype Systems																	
6.1.1	Deliver (Bench) Prototype IF System																	
6.1.2	Testing and Design Refinement																	
6.1.3	Procure/Fab Field Prototypes																	
6.1.4	Deliver IF Field Prototypes to Test Interfeometer																	
6.1.5	Field Prototype testing and Design Refinement																	
6.1.6	Preproduction Review																	
6.1.7	Final Documentation and Design Modifications																	
6.1.8	Release for Manufacture																	
6.2	Production test and lab equipment																	
6.3	IF Multiplexer					\$	800		\$	89	\$	107	\$	711	\$	109	\$	729
6.4	IF Demultiplexer					\$	400		\$	44	\$	53	\$	356	\$	55	\$	364
6.5	IF Matrix Switch					\$	320		\$	36	\$	43	\$	284	\$	44	\$	292
6.6	Baseband Converter					\$	800		\$	89	\$	107	\$	711	\$	109	\$	729
6.7	Power supply module					\$	200		\$	22	\$	27	\$	178	\$	27	\$	182
6.8	Bins / Racks (assemble and test)					\$	80		\$	9	\$	11	\$	71	\$	11	\$	73
7	Optical Fiber System	12	12	\$	176				\$	26	\$	176	\$	27	\$	180		
7.1	Optical Fiber System: Prototype Systems																	
7.1.1	Deliver (Bench) Prototype FO System																	
7.1.2	Testing and Design Refinement																	
7.1.3	Procure/Fab Field Prototypes																	
7.1.4	Deliver FO Field Prototypes to Test Interfeometer																	
7.1.5	Field Prototype testing and Design Refinement																	
7.1.6	Preproduction Review																	
7.1.7	Final Documentation and Design Modifications																	
7.1.8	Release for Manufacture																	
7.1	Production test and lab equipment																	
7.2	IF TX / RX					\$	1,200		\$	133	\$	160	\$	1,067	\$	164	\$	1,093
7.3	LO Reference TX / RX					\$	200		\$	22	\$	27	\$	178	\$	27	\$	182
7.4	Microwave Round-trip Phase TX / RX					\$	200		\$	22	\$	27	\$	178	\$	27	\$	182
7.5	Monitor / Control TX / RX					\$	100		\$	11	\$	13	\$	89	\$	14	\$	91
7.6	Power supply module					\$	200		\$	22	\$	27	\$	178	\$	27	\$	182
7.7	Bins / Racks (assemble and test)					\$	80		\$	9	\$	11	\$	71	\$	11	\$	73
8	Correlator	36	36	\$	527	\$	2,000		\$	281	\$	595	\$	2,246	\$	610	\$	2,302
8.1	Digital Sampler, 4 GHz	6	12	\$	117	\$	428		\$	61	\$	128	\$	484	\$	131	\$	497
8.1.1	Refine Design																	
8.1.2	Release Digital Sampler for Manufacture																	
8.1.3	Contract Materials																	
8.1.4	Assembly																	
8.1.5	Validation and Delivery																	

8.2	Digital FIR Filter				2	2	\$ 29	\$ 533		\$ 62	\$ 146	\$ 500	\$ 149	\$ 512
8.2.1	Prototype testing on Test Interferometer													
8.2.2	Design Refinement													
8.2.3	Release FIR Filter for manufacture													
8.2.4	Chip Fabrication													
8.2.5	Assembly													
8.2.6	Validation and Delivery													
8.3	Custom Boards													
8.3.1	Correlator Board													
8.3.1.1	Prototype assembly													
8.3.1.2	Prototype test													
8.3.1.3	Design modifications													
8.3.1.4	Fab, assemble and test with design mods													
8.4	Correlator Chip													
8.4.1	Prototype chip fabrication													
8.4.2	Prototype chip test													
8.4.3	Design modifications													
8.4.4	Fabricate and test design mods													
8.4.5	Fabricate production run													
8.5	Racks													
8.5.1	Design control wiring													
8.5.2	Design signal wiring													
8.5.3	Order parts													
8.5.4	Assemble prototypes													
8.6	Software													
8.7	Prototype Correlator Production													
8.7.1	Order parts													
8.7.2	Assemble													
8.7.3	Test													
8.7.4	Deliver Prototype Correlator to VLA site													
8.8	Site Correlator Production													
8.8.1	First 1/4 correlator													
8.8.1.1	Determine configuration													
8.8.1.2	Order parts													
8.8.1.3	Assemble													
8.8.1.4	Test													
8.8.1.5	Deliver 1/4 Correlator to MMA site													
8.8.2	Second 1/4 correlator													
8.8.2.1	Order parts													
8.8.2.2	Assemble													
8.8.2.3	Test													
8.8.2.4	Deliver 1/4 Correlator to MMA site													
8.8.3	Third 1/4 correlator													
8.8.3.1	Order parts													
8.8.3.2	Assemble													
8.8.3.3	Test													
8.8.3.4	Deliver 1/4 Correlator to MMA site													
8.8.4	Fourth 1/4 correlator													
8.8.4.1	Order parts													
8.8.4.2	Assemble													
8.8.4.3	Test													

8.8.4.4	Deliver 1/4 Correlator to MMA site													
8.9	Continued Support													
9	Computing							\$ 50		\$ 15	\$ 50	\$ 15	\$ 51	
9.1	Control Software													
9.1.1	Test Interferometer Control & Analysis													
9.1.2	MMA correlator software	52					\$ 451		\$ 68	\$ 451	\$ 69	\$ 462		
9.1.3	Multi-antenna & sub-array control													
9.1.4	Operators & Observers interfaces	26					\$ 225		\$ 34	\$ 225	\$ 35	\$ 231		
9.1.5	Deliver Control Software													
9.1.6	Maintenance													
9.2	Scheduling													
9.2.1	Static scheduling system	10					\$ 87		\$ 13	\$ 87	\$ 13	\$ 89		
9.2.2	Dynamic scheduling simulations	12					\$ 104		\$ 16	\$ 104	\$ 16	\$ 107		
9.2.3	Dynamic scheduling prototype													
9.2.4	Dynamic scheduling implementation													
9.2.5	Initial Operations with Dynamic Scheduling													
9.3	Proposal Preparation Software													
9.3.1	Prototype	6					\$ 52		\$ 8	\$ 52	\$ 8	\$ 53		
9.3.2	Production version													
9.4	Image Pipeline													
9.4.1	Automated calibration & imaging heuristics	6					\$ 52		\$ 8	\$ 52	\$ 8	\$ 53		
9.4.2	Prototype image pipeline													
9.4.3	Parallelization studies and implementation													
9.4.4	Initial Image Pipeline Operations													
9.4.5	Production image pipeline													
9.5	Archiving													
9.5.1	Prototype distributed archive	10					\$ 87		\$ 13	\$ 87	\$ 13	\$ 89		
9.5.2	Evaluate storage hardware													
9.5.3	Production archive													
9.5.4	Data Archive operational													
9.6	Post-processing													
9.6.1	Define MMA Data formats	6					\$ 52		\$ 8	\$ 52	\$ 8	\$ 53		
9.6.2	MMA filler & format conversions													
9.6.3	MMA-specific calibrations	6					\$ 52		\$ 8	\$ 52	\$ 8	\$ 53		
9.6.4	MMA Post-processing begins													
9.6.5	Maintenance													
10	System Integration							\$ 50		\$ 15	\$ 50	\$ 15	\$ 51	
10.4	Test Interferometer Site Preparation													
10.4.1	Complete Office and Lab Space Preparation													
10.4.2	Cabling													
10.4.3	Test Interferometer Site Complete													
10.10.4	Prototype Antenna Outfitting													
10.10.4.1	Cabling													
10.10.4.2	Instrumentation													
10.10.4.3	Eval. Rcvr. #1 / Ant. #1 Integration		24		12		\$ 293		\$ 44	\$ 293	\$ 45	\$ 300		
10.10.4.4	Antenna #1 Outfitting Complete													
10.10.5	Integration Holography System/Antenna													
10.10.6	Integration Metrology/Antenna													
10.10.7	Antenna #1 Integration & Testing													

10.10.8	Prot. Rcvr. Test & Evaluation																			
10.10.9	Antenna #2 Outfitting																			
10.10.9.1	Cabling																			
10.10.9.2	Instrumentation																			
10.10.9.3	Eval. Rcvr. #2 / Ant. #2 Integration																			
10.10.9.4	Antenna #2 Outfitting Complete																			
10.11	Test Interferometer		6	24	12	\$	345					\$	52	\$	345	\$	53	\$	353	
10.11.1	Antenna Evaluation & Characterization																			
10.11.1.1	Antenna Verification																			
10.11.1.4	Holography																			
10.11.1.5	Beam and Sidelobes																			
10.11.1.6	Gain vs. Elevation: Spillover Temp																			
10.11.1.7	Effect of Sun in & Near the Beam																			
10.11.2	Engineering Recommendations re Prod. Ant.																			
10.11.3	Revise Interface Specifications																			
10.11.5	Operations Personnel Training		5				\$	41		\$	41		\$	-	\$	-	\$	-	\$	-
10.11.5.1	Recruit Initial Chile Ops Staff																			
10.11.5.2	Array Operations																			
10.11.5.3	Engineering Maintenance																			
10.11.5.4	Scientific Support & Analysis																			
10.12.2	Relocate Ops Staff to Chile																			
10.8.4.6	Start On-site Operations																			
10.12	Disassemble Test Interferometer																			
10.12.1	Prepare & Ship Antenna #1, #2																			
10.12.3	Restore Facilities at VLA Site																			
10.13	On Site System Integration																			
11	Calibration and Imaging		1				\$	8				\$	1	\$	8	\$	1	\$	8	
11.1	Radiometric Phase Design & Prototype																			
11.1.1	Complete 183GHz Phase Mon Prototype																			
11.1.2	Demo 183 GHz Phase Monitor Radiometer on-Site																			
11.1.3	Design Refinement																			
11.1.4	Release Phase Mon Radiometer for manufacture																			
11.2	Production Fab of Phase Monitor Radiometer							\$	681		\$	76	\$	182	\$	605	\$	186	\$	620
11.2.1	Contract Subassembly Fabrication																			
11.2.1.1	Radiometer & Local Oscillator																			
11.2.1.2	Spectrometer																			
11.2.1.3	Feed, Window, lens, instrumentation																			
11.2.1.4	M/C Interface																			
11.2.2	Assembly & Test																			
11.2.3	Deliver Production Radiometers																			
11.2.4	Integration in Receiver Package																			
11.2.5	Verification on-Site																			
11.3	Production Fabrication of Dual-load Amp Cal Sys							\$	291		\$	32	\$	78	\$	259	\$	80	\$	265
11.3.1	Design Refinement																			
11.3.2	Release Phase Mon Radiometer for manufacture																			
11.3.3	Contract Subassembly																			
11.3.3.1	Machining																			
11.3.3.2	Load Fabrication																			
11.3.3.3	Motors, Servo																			
11.3.3.4	M/C Interface																			
11.3.4	Assembly & Test																			

11.3.5	Integration on Production Antennas												
11.4	Imaging Studies & Project Support	48				\$ 390		\$ 195		\$ 29	\$ 195	\$ 30	\$ 200
11.5	Imaging Algorithm Development	8	4			\$ 100				\$ 15	\$ 100	\$ 15	\$ 102
TOTALS						\$ 10,353	\$ 54,089	\$ 836	\$ 6,596	\$ 10,353	\$ 57,011	\$ 11,498	\$ 58,081

Millimeter Array Construction 2003

WBS	Name	Scientists Work-Months	Programmers Work Months	Engineers Work-Months	Technicians Work-Months	Personnel Cost	Materials and Supplies	Transfer to Operations	Adjustment to Scope	Contingency	Sum Cost	Inflated Contingency	Inflated Sum
1	Administration												
1.1	Project Management	72			48	\$ 819		\$ 215		\$ 91	\$ 605	\$ 95	\$ 635
1.1.1	Management, Planning, and Oversight						\$ 600			\$ -	\$ 600	\$ -	\$ 630
1.1.2	Business Operations						\$ 90			\$ 14	\$ 90	\$ 14	\$ 95
1.1.3	Chilean Operations						\$ 50			\$ 8	\$ 50	\$ 8	\$ 53
1.1.4	Safety and Health												
1.1.5	Personnel												
1.1.6	Project Science Office												
1.1.7	AUI Management						\$ 350			\$ -	\$ 350	\$ -	\$ 368
1.2	Engineering			24	12	\$ 293	\$ 20			\$ 47	\$ 313	\$ 49	\$ 328
1.2.1	System Engineering--Phase II												
1.2.2	Documentation System												
1.2.3	Production Engineering												
1.3	US Facilities												
1.3.1	CDL Permanent Facilities						\$ 600			\$ -	\$ 600	\$ -	\$ 630
1.3.2	Manufacturing Facilities						\$ 100			\$ 15	\$ 100	\$ 16	\$ 105
1.3.3	Common Infrastructure						\$ 200			\$ 30	\$ 200	\$ 32	\$ 210
2	Site Development			12		\$ 117	\$ 50			\$ 28	\$ 167	\$ 29	\$ 175
2.1	Review Legalities Regarding Array and OSF Sites												
2.2	Maintain Mining claims						\$ 25			\$ -	\$ 25	\$ -	\$ 26
2.3	Contract A&E Studies												
2.4	Hire Construction Manager for Chile												
2.5	Array Site												
2.5.1	Prepare Site Development Bid Packages												
2.5.1.1	Prepare Package for Array Site												
2.5.1.2	Review Bid Packages												
2.5.1.3	Bid Civil Works Construction												
2.5.2	Evaluate Array Site Bid Response												
2.5.2.1	Review Bids												
2.5.2.2	Recommend Contractors												
2.5.2.3	Award Array Site Contracts												
2.5.3	Contract Array Site Civil Works						\$ 5,836		\$ 718	\$ 1,024	\$ 5,119	\$ 1,076	\$ 5,378
2.5.3.1	Array Site												
2.5.3.2	Inspect Completed Site Constr												
2.5.3.3	Accept Site Facility												
2.6	Operations Support Facility												
2.6.1	Prepare OSF Bid Packages												
2.6.1.1	Prepare Package for OSF												
2.6.1.2	Review Bid Packages												
2.6.1.3	Bid Civil Works Construction												
2.6.2	Evaluate OSF Bid Response												
2.6.2.1	Review Bids												
2.6.2.2	Recommend Contractors												
2.6.2.3	Award Contracts												

2.6.3	Contract OSF Civil Works					\$ 3,546	\$ 215	\$ 168	\$ 644	\$ 3,164	\$ 676	\$ 3,324
2.6.3.1	Operations Support Facility											
2.6.3.2	Inspect Completed OSF Constr											
2.6.3.3	Accept OSF Facility											
2.7	OSF/Array Link											
2.7.1	Prepare OSF/Array Link Bid Package											
2.7.1.1	Prepare Package for OSF/Array F/O Link											
2.7.1.2	Review Bid Package											
2.7.1.3	Bid OSF/Array Link Construction											
2.7.2	Evaluate Bid Response											
2.7.2.1	Review Bids											
2.7.2.2	Recommend Contractors											
2.7.2.3	Award Contracts											
2.7.3	Contract Civil Works											
2.7.3.1	OSF/Array Link											
2.7.3.2	Inspect Completed OSF/Array Link Constr											
2.7.3.3	Accept OSF/Array Link											
2.8	Prepare for Instrument Assembly											
2.8.1	Equip Array Site											
2.8.2	Equip Operations Support Facility											
3	Antenna											
3.1	Antenna Engineering Support											
3.3.40	Acceptance Tests Antenna #1											
3.3.45	Delivery of Antenna #1											
3.8.10	Sign Transporter Contract											
3.8.15	Transporter Acceptance tests											
3.8.20	Deliver/Accept Transporter #1											
3.7	Procurement of Antenna #2											
3.7.1	Antenna #2 Contract Supervision											
3.7.2	Antenna #2 Acceptance tests											
3.8	Negotiate Production Antenna Contract											
3.9	Sign Contract for Production Antennas					\$ 1,000			\$ 200	\$ 1,000	\$ 210	\$ 1,051
3.10	Antenna Contract Supervision											
3.11	Accept Antenna #3 at OSF	3			\$ 29	\$ 2,832			\$ 571	\$ 2,861	\$ 600	\$ 3,006
3.12	Prepare Antenna #3											
3.12.1	Outfit & Verify Ant #3 at OSF											
3.12.2	Move, Install & Verify Ant #3 on Site											
3.13	Accept Antenna #4 at OSF	3			\$ 29	\$ 2,832			\$ 571	\$ 2,861	\$ 600	\$ 3,006
3.14	Prepare Antenna #4											
3.14.1	Outfit & Verify Ant #4 at OSF											
3.14.2	Move, Install & Verify Ant #4 on Site											
3.15	Accept Antenna#5 at OSF	3			\$ 29	\$ 2,832			\$ 571	\$ 2,861	\$ 600	\$ 3,006
3.16	Prepare Antenna #5											
3.16.1	Outfit & Verify Ant #5 at OSF											
3.16.2	Move, Install & Verify Ant #5 on Site											
3.17	Accept Antenna#6 at OSF	3			\$ 29	\$ 2,832			\$ 571	\$ 2,861	\$ 600	\$ 3,006
3.18	Prepare Antenna #6											
3.18.1	Outfit & Verify Ant #6 at OSF											
3.18.2	Move, Install & Verify Ant #6 on Site											

4.1.8	Fab Rcvr Pckg Instrumentation & Electronics		12	6	12	\$ 221	\$ 100		\$ 36	\$ 46	\$ 285	\$ 48	\$ 300
4.1.9	Fabricate Receiver Inserts			24	24	\$ 351	\$ 100		\$ 50	\$ 63	\$ 401	\$ 66	\$ 421
4.1.10	Assemble Receiver Package			24	36	\$ 410	\$ 80		\$ 54	\$ 67	\$ 435	\$ 70	\$ 457
4.1.10.1	Integrate Rcvr Instrumentation & subassy												
4.1.10.2	Deliver Receiver Package #1-6												
4.1.10.3	Deliver Receiver Package #7-16												
4.1.10.4	Deliver Receiver Package #17-26												
4.1.10.5	Deliver Receiver Package #27-36												
4.1.10.6	Deliver Receiver Package #37-40												
4.2	SIS Receiver Modules												
4.2.1	211-275 GHz Module												
4.2.1.1	SIS Mixer												
4.2.1.1.1	Design, Fab and Test Mixer Design												
4.2.1.1.2	Deliver Production Design												
4.2.1.1.3	Fabricate Production Mixers												
4.2.1.2	Design & Verify Optics												
4.2.1.3	Design Module												
4.2.1.4	Contract Fabrication				4	\$ 20	\$ 100		\$ 13	\$ 20	\$ 106	\$ 21	\$ 112
4.2.1.4.1	Machine Mixer Blocks, Feed, WG, Lenses												
4.2.1.4.2	Assemble Modules												
4.2.1.5	Install SIS Mixer & Test Modules			18	36	\$ 351	\$ 30		\$ 42	\$ 50	\$ 339	\$ 53	\$ 356
4.2.1.6	Deliver 211-275 GHz Receiver Modules												
4.2.1.6.1	Deliver Modules #1-7												
4.2.1.6.2	Deliver Modules #8-26												
4.2.1.6.3	Deliver Modules #27-40												
4.2.2	602-720 GHz Module												
4.2.2.1	SIS Mixer												
4.2.2.1.1	Design, Fabricate and Test Mixer Design												
4.2.2.1.2	Deliver Production Design												
4.2.2.1.3	Fabricate Production Mixers												
4.2.2.2	Design & Verify Optics												
4.2.2.3	Design Module												
4.2.2.4	Contract Fabrication				4	\$ 20	\$ 100		\$ 120	\$ -	\$ -	\$ -	\$ -
4.2.2.4.1	Machine Mixer Blocks, Feed, WG, Lenses												
4.2.2.4.2	Assemble Modules												
4.2.2.5	Install SIS Mixer and Test Modules			18	36	\$ 351	\$ 30		\$ 381	\$ -	\$ -	\$ -	\$ -
4.2.2.6	Deliver 602-720 GHz Receiver Modules												
4.2.2.6.1	Deliver Modules #1-7												
4.2.2.6.2	Deliver Modules #8-26												
4.2.2.6.3	Deliver Modules #27-40												
4.2.3	275-370 GHz Receiver Module			36	24	\$ 468	\$ 100		\$ 63	\$ 78	\$ 505	\$ 82	\$ 530
4.2.3.1	SIS Mixer								\$ -	\$ -	\$ -	\$ -	\$ -
4.2.3.1.1	Design, Fabricate and Test Mixer Design												
4.2.3.1.2	Deliver Production Design												
4.2.3.1.3	Fabricate Production Mixers												
4.2.3.2	Design & Verify Optics												
4.2.3.3	Design Module												
4.2.3.4	Contract Fabrication				4	\$ 20	\$ 100		\$ 13	\$ 20	\$ 106	\$ 21	\$ 112
4.2.3.4.1	Machine Mixer Blocks, Feed, WG, Lenses												
4.2.3.4.2	Assemble Modules												

4.2.3.5	Install SIS Mixer and Test Modules		12	24	\$	234	\$	40		\$	30	\$	37	\$	244	\$	39	\$	256
4.2.3.6	Deliver 275-370 GHz Receiver Module																		
4.2.3.6.1	Deliver Modules #1-5																		
4.2.3.6.2	Deliver Modules #6-30																		
4.2.3.6.3	Deliver Modules #30-40																		
4.2.4	91-119 GHz Receiver Module		36	24	\$	468	\$	100		\$	63	\$	78	\$	505	\$	82	\$	530
4.2.4.1	SIS Mixer									\$	-	\$	-	\$	-	\$	-	\$	-
4.2.4.1.1	Design, Fabricate & Test Mixer Design																		
4.2.4.1.2	Deliver Production Design																		
4.2.4.1.3	Fabricate Production Mixers																		
4.2.4.2	Design & Verify Optics																		
4.2.4.3	Design Module																		
4.2.4.4	Contract Fabrication			4	\$	20	\$	100		\$	13	\$	20	\$	106	\$	21	\$	112
4.2.4.4.1	Machine Mixer Blocks, Feed, WG, Lenses																		
4.2.4.4.2	Assemble Modules																		
4.2.4.5	Install SIS Mixer and Test Modules		12	24	\$	234	\$	40		\$	30	\$	37	\$	244	\$	39	\$	256
4.2.4.6	Deliver 91-119 GHz Receiver Modules																		
4.2.4.6.1	Deliver Modules #1-5																		
4.2.4.6.2	Deliver Modules #6-30																		
4.2.4.6.3	Deliver Modules # 31-40																		
4.2.5	163-211 GHz Receiver Module		24	24	\$	351	\$	400		\$	83	\$	116	\$	668	\$	122	\$	701
4.2.5.1	SIS Mixer									\$	-	\$	-	\$	-	\$	-	\$	-
4.2.5.1.1	Design, Fabricate & Test Mixer Design																		
4.2.5.1.2	Deliver Production Design																		
4.2.5.1.3	Fabricate Production Mixers																		
4.2.5.2	Design & Verify Optics																		
4.2.5.3	Design Module																		
4.2.5.4	Contract Fabrication			2	\$	10	\$	100		\$	12	\$	19	\$	98	\$	20	\$	102
4.2.5.4.1	Machine Mixer Blocks, Feed, WG, Lenses																		
4.2.5.4.2	Assemble Modules																		
4.2.5.5	Install SIS Mixer and Test																		
4.2.5.6	Deliver 163-211 GHz Receiver Modules																		
4.2.5.6.1	Deliver Modules #1-5																		
4.2.5.6.2	Deliver Modules #6-30																		
4.2.5.6.3	Deliver Modules #31-40																		
4.2.6	385-500 GHz Receiver Module		24	24	\$	351	\$	400		\$	751	\$	-	\$	-	\$	-	\$	-
4.2.6.1	SIS Mixer									\$	-	\$	-	\$	-	\$	-	\$	-
4.2.6.1.1	Design, Fabricate & Test Mixer Design																		
4.2.6.1.2	Deliver Production Design																		
4.2.6.1.3	Fabricate Production Mixers																		
4.2.6.2	Design and Verify Optics																		
4.2.6.3	Design Module																		
4.2.6.4	Contract Fabrication			2	\$	10	\$	100		\$	110	\$	-	\$	-	\$	-	\$	-
4.2.6.4.1	Machine Mixer Blocks, Feed, WG, Lenses																		
4.2.6.4.2	Assemble Modules																		
4.2.6.5	Install SIS Mixer and Test																		
4.2.6.6	Deliver 385-500 GHz Receiver Modules																		
4.2.6.6.1	Deliver Modules #1-5																		
4.2.6.6.2	Deliver Modules #6-30																		
4.2.6.6.3	Deliver Modules #31-40																		

4.2.7	125-163 GHz Receiver Module																		
4.2.7.1	SIS Mixer																		
4.2.7.1.1	Design, Fabricate & Test Mixer Design																		
4.2.7.1.2	Deliver Production Design																		
4.2.7.1.3	Fabricate Production Mixers																		
4.2.7.2	Design & Verify Optics	6			\$	59	\$	50		\$	12	\$	16	\$	96	\$	17	\$	101
4.2.7.3	Design Module	6			\$	59	\$	50		\$	12	\$	16	\$	96	\$	17	\$	101
4.2.7.4	Contract Fabrication																		
4.2.7.4.1	Machine Mixer Blocks, Feed, WG, Lenses																		
4.2.7.4.2	Assemble Modules																		
4.2.7.5	Install SIS Mixer and Test																		
4.2.7.6	Deliver 125-163 GHz Receiver Modules																		
4.2.7.6.1	Deliver 125-163 GHz Modules #1-5																		
4.2.7.6.2	Deliver 125-163 GHz Modules #6-30																		
4.2.7.6.3	Deliver 125-163 GHz Modules #31-40																		
4.3	HFET Receiver Modules	6	12	\$	117	\$	50		\$	19	\$	22	\$	148	\$	23	\$	156	
4.3.1	Contract for HFET Wafer																		
4.3.2	Receive Diced HFET Wafer																		
4.3.3	33-45 GHz Module																		
4.3.3.1	Design Module																		
4.3.3.2	Design & Verify Optics																		
4.3.3.3	Contract Fabrication																		
4.3.3.3.1	Machine Blocks, Feed, WG, Lenses																		
4.3.3.3.2	Assemble Modules																		
4.3.3.3.3	Flip-in Mirror																		
4.3.4	Install HFET & Test Modules																		
4.3.5	Deliver 33-45 GHz Receiver Modules																		
4.3.5.1	Deliver Modules #1-20																		
4.3.5.2	Deliver Modules #21-40																		
4.3.6	67-95 GHz Module																		
4.3.6.1	Design Amplifier																		
4.3.6.2	Design Module																		
4.3.6.3	Design & Verify Optics																		
4.3.6.4	Contract Fabrication																		
4.3.6.4.1	Machine Blocks, Feed, WG, Lenses																		
4.3.6.4.2	Assemble Modules																		
4.3.6.5	Install HFET & Test Modules																		
4.3.6.6	Deliver 67-95 GHz Receiver Modules																		
4.3.6.6.1	Deliver Modules 67-95GHz #1-20																		
4.3.6.6.2	Deliver Modules 67-95GHz #21-40																		
5	LO System																		
5.1	LO Reference: Prototype Systems																		
5.1.1	Deliver: Bench Prototype																		
5.1.2	Testing and Design Refinement																		
5.1.3	Procure/Fab Field Prototypes																		
5.1.4	Deliver: LO Ref Field Prototypes																		
5.1.5	Field Prototype testing and Design Refinement																		
5.1.6	Preproduction Review																		

5.1.7	Final Documentation and Design Modifications																	
5.1.8	Release for Manufacture																	
5.2	LO Reference: Production System	12	48	\$	351				\$	53	\$	351	\$	55	\$	369		
5.1.1	Production test and lab equipment																	
5.1.2	H-maser Frequency Standard (& Rb)				\$	300			\$	33	\$	40	\$	267	\$	42	\$	280
5.1.3	8 GHz PL Oscillator & Distributor				\$	1			\$	0	\$	0	\$	1	\$	0	\$	1
5.1.4	10 GHz PL Oscillator & Distributor				\$	1			\$	0	\$	0	\$	1	\$	0	\$	1
5.1.5	12 GHz PL Oscillator & Distributor				\$	1			\$	0	\$	0	\$	1	\$	0	\$	1
5.1.6	14 GHz PL Oscillator & Distributor				\$	1			\$	0	\$	0	\$	1	\$	0	\$	1
5.1.7	3.2-5.2 GHz Synthesizer				\$	8			\$	1	\$	1	\$	7	\$	1	\$	7
5.1.8	3.2 -5.2 GHz PLO and Fringe Generator				\$	160			\$	18	\$	21	\$	142	\$	22	\$	149
5.1.9	Sampler Clock 4 GHz PL Osc & Distributor				\$	1			\$	0	\$	0	\$	1	\$	0	\$	1
5.1.10	LO Ref Generator				\$	2			\$	0	\$	0	\$	2	\$	0	\$	2
5.1.11	LO Ref Distributor - Control Bldg				\$	1			\$	0	\$	0	\$	1	\$	0	\$	1
5.1.12	Microwave Round-trip Phase Measurement				\$	60			\$	7	\$	8	\$	53	\$	8	\$	56
5.1.13	10-15 GHz Frequency Synthesizer				\$	100			\$	11	\$	13	\$	89	\$	14	\$	93
5.1.14	First LO Fringe Generator				\$	20			\$	2	\$	3	\$	18	\$	3	\$	19
5.1.15	16 GHz PL Oscillator				\$	40			\$	4	\$	5	\$	36	\$	6	\$	37
5.1.16	26 GHz PL Oscillator				\$	40			\$	4	\$	5	\$	36	\$	6	\$	37
5.1.17	LO Ref Distributor - Antenna				\$	20			\$	2	\$	3	\$	18	\$	3	\$	19
5.1.18	VXCO Clean-up Loop				\$	20			\$	2	\$	3	\$	18	\$	3	\$	19
5.1.19	Power supply module				\$	60			\$	7	\$	8	\$	53	\$	8	\$	56
5.1.20	Bins / Racks (assemble and test)				\$	16			\$	2	\$	2	\$	14	\$	2	\$	15
5.3	Millimeter LO Drivers																	
5.3.1	Design and System Integration	3		\$	29				\$	4	\$	29	\$	5	\$	31		
5.3.2	72-95 GHz Source		3	\$	15				\$	2	\$	2	\$	13	\$	2	\$	14
5.3.2.1	Contract Procurement and Fabrication																	
5.3.2.1.1	YIG-tuned Oscillator																	
5.3.2.1.2	18.00 - 23.75 GHz 10 db Amplifier																	
5.3.2.1.3	18.00 - 23.75 GHz x2 Multiplier																	
5.3.2.1.4	36.0 - 47.5 GHz 10 db Amplifier																	
5.3.2.1.5	36.0 - 47.5 GHz x2 Multiplier																	
5.3.2.1.6	Mount and Tuning circuitry																	
5.3.2.2	Assembly and Test																	
5.3.2.3	Deliver 72 - 95 GHz LO Sources																	
5.3.2.3.1	Deliver Modules #1-6																	
5.3.2.3.2	Deliver Modules #7-24																	
5.3.2.3.3	Deliver Modules #25-40																	
5.3.3	100-120 GHz Source		3	\$	15			\$	15	\$	-	\$	-	\$	-	\$	-	
5.3.3.1	Contract Procurement and Fabrication																	
5.3.3.1.1	YIG-tuned Oscillator																	
5.3.3.1.2	25.00 - 30.00 GHz 10 db Amplifier																	
5.3.3.1.3	15.00 - 30.00 GHz x2 Multiplier																	
5.3.3.1.4	50.0 - 60.0 GHz 10 db Amplifier																	
5.3.3.1.5	50-60 GHz x2 Multiplier																	
5.3.3.1.6	Mount and Tuning circuitry																	
5.3.3.2	Assembly and Test																	
5.3.3.3	Deliver 100 - 120 GHz LO Sources																	
5.3.3.3.1	Deliver Modules #1-3																	
5.3.3.3.2	Deliver Modules #4-21																	
5.3.3.3.3	Deliver Modules #22-40																	

5.3.4	87 - 108 GHz Source			6	8	\$ 98	\$ 240		\$ 38	\$ 75	\$ 300	\$ 79	\$ 315
5.3.4.1	Contract Procurement and Fabrication												
5.3.4.1.1	YIG-tuned Oscillator												
5.3.4.1.2	21.75-27.00 GHz 10 db Amplifier												
5.3.4.1.3	21.75-27.00 GHz x2 Multiplier												
5.3.4.1.4	43.5-54.0 GHz 10 db Amplifier												
5.3.4.1.5	43.5-54.0 GHz x2 Multiplier												
5.3.4.1.6	Mount and Tuning Circuitry												
5.3.4.2	Assembly and Test												
5.3.4.3	Deliver 87 - 108 GHz LO Sources												
5.3.4.3.1	Deliver Modules #1-6												
5.3.4.3.2	Deliver Modules #7-20												
5.3.4.3.3	Deliver Modules #21-35												
5.3.4.3.4	Deliver Modules #36-40												
5.3.5	65 - 85 GHz Source			6	8	\$ 98	\$ 240		\$ 38	\$ 75	\$ 300	\$ 79	\$ 315
5.3.5.1	Contract Procurement and Fabrication												
5.3.5.1.1	YIG-tuned Oscillator												
5.3.5.1.2	16.25-21.25 GHz 10 db Amplifier												
5.3.5.1.3	16.25-21.25 GHz x2 Multiplier												
5.3.5.1.4	32.5-42.5 GHz 10 db Amplifier												
5.3.5.1.5	32.5-42.5 GHz x2 Multiplier												
5.3.5.1.6	Mount and Tuning Circuitry												
5.3.5.2	Assembly and Test												
5.3.5.3	Deliver 65 - 85 GHz LO Sources												
5.3.5.3.1	Deliver Modules #1-6												
5.3.5.3.2	Deliver Modules #7-20												
5.3.5.3.3	Deliver Modules #21-35												
5.3.5.3.4	Deliver Modules #36-40												
5.4	Millimeter LO Multiplier Chains												
5.4.1	Design and System Integration			2		\$ 20				\$ 3	\$ 20	\$ 3	\$ 20
5.4.2	211 - 275 GHz Receiver LO			3	18	\$ 117	\$ 50		\$ 19	\$ 27	\$ 148	\$ 28	\$ 156
5.4.2.1	Contract Fabrication												
5.4.2.1.1	X3 Diode for 72-95 GHz Source												
5.4.2.1.2	Machine Mount												
5.4.2.1.3	Bias and Control circuits												
5.4.2.2	Assemble Multiplier and Test												
5.4.2.3	Integrate Source and Multiplier; test												
5.4.2.4	Deliver 211-275 GHz Rcvr LO Modules												
5.4.2.4.1	Deliver Modules #1-3												
5.4.2.4.2	Deliver Modules #4-21												
5.4.2.4.3	Deliver Modules #22-40												
5.4.3	602 - 720 GHz Receiver LO			3	18	\$ 117	\$ 50		\$ 167	\$ -	\$ -	\$ -	\$ -
5.4.3.1	Contract Fabrication												
5.4.3.1.1	X2 Diode for 100-120 GHz Source												
5.4.3.1.2	X3 Diode for 200-240 GHz Input												
5.4.3.1.3	Machine Mount												
5.4.3.1.4	Bias and Control circuits												
5.4.3.2	Assemble Multipliers and Test												
5.4.3.3	Integrate Source and Multipliers; test												

5.4.7.4.2	Deliver Modules #7-18																				
5.4.7.4.3	Deliver Modules #19-34																				
5.4.7.4.4	Deliver Modules #35-40																				
5.4.8	33-45 GHz Receiver LO																				
5.4.8.1	Design & Fab Selection & Coupling from Sources																				
6	IF System		12	36	\$	293					\$	44	\$	293	\$	46	\$	307			
6.1	IF System: Prototype Systems																				
6.1.1	Deliver (Bench) Prototype IF System																				
6.1.2	Testing and Design Refinement																				
6.1.3	Procure/Fab Field Prototypes																				
6.1.4	Deliver IF Field Prototypes to Test Interfeometer																				
6.1.5	Field Prototype testing and Design Refinement																				
6.1.6	Preproduction Review																				
6.1.7	Final Documentation and Design Modifications																				
6.1.8	Release for Manufacture																				
6.2	Production test and lab equipment																				
6.3	IF Multiplexer					\$	160		\$	18	\$	21	\$	142	\$	22	\$	149			
6.4	IF Demultiplexer					\$	80		\$	9	\$	11	\$	71	\$	11	\$	75			
6.5	IF Matrix Switch					\$	64		\$	7	\$	9	\$	57	\$	9	\$	60			
6.6	Baseband Converter					\$	160		\$	18	\$	21	\$	142	\$	22	\$	149			
6.7	Power supply module					\$	40		\$	4	\$	5	\$	36	\$	6	\$	37			
6.8	Bins / Racks (assemble and test)					\$	16		\$	2	\$	2	\$	14	\$	2	\$	15			
7	Optical Fiber System		12	36	\$	293					\$	44	\$	293	\$	46	\$	307			
7.1	Optical Fiber System: Prototype Systems																				
7.1.1	Deliver (Bench) Prototype FO System																				
7.1.2	Testing and Design Refinement																				
7.1.3	Procure/Fab Field Prototypes																				
7.1.4	Deliver FO Field Prototypes to Test Interfeometer																				
7.1.5	Field Prototype testing and Design Refinement																				
7.1.6	Preproduction Review																				
7.1.7	Final Documentation and Design Modifications																				
7.1.8	Release for Manufacture																				
7.1	Production test and lab equipment																				
7.2	IF TX / RX					\$	240		\$	27	\$	32	\$	213	\$	34	\$	224			
7.3	LO Reference TX / RX					\$	40		\$	4	\$	5	\$	36	\$	6	\$	37			
7.4	Microwave Round-trip Phase TX / RX					\$	40		\$	4	\$	5	\$	36	\$	6	\$	37			
7.5	Monitor / Control TX / RX					\$	20		\$	2	\$	3	\$	18	\$	3	\$	19			
7.6	Power supply module					\$	40		\$	4	\$	5	\$	36	\$	6	\$	37			
7.7	Bins / Racks (assemble and test)					\$	16		\$	2	\$	2	\$	14	\$	2	\$	15			
8	Correlator		36	36	\$	527	\$	1,000			\$	170	\$	328	\$	345	\$	1,426			
8.1	Digital Sampler, 4 GHz		6	12	\$	117	\$	428			\$	61	\$	128	\$	134	\$	509			
8.1.1	Refine Design																				
8.1.2	Release Digital Sampler for Manufacture																				
8.1.3	Contract Materials																				
8.1.4	Assembly																				
8.1.5	Validation and Delivery																				

8.2	Digital FIR Filter			2	2	\$	29	\$	533		\$	62	\$	146	\$	500	\$	153	\$	525
8.2.1	Prototype testing on Test Interferometer																			
8.2.2	Design Refinement																			
8.2.3	Release FIR Filter for manufacture																			
8.2.4	Chip Fabrication																			
8.2.5	Assembly																			
8.2.6	Validation and Delivery																			
8.3	Custom Boards																			
8.3.1	Correlator Board																			
8.3.1.1	Prototype assembly																			
8.3.1.2	Prototype test																			
8.3.1.3	Design modifications																			
8.3.1.4	Fab, assemble and test with design mods																			
8.4	Correlator Chip																			
8.4.1	Prototype chip fabrication																			
8.4.2	Prototype chip test																			
8.4.3	Design modifications																			
8.4.4	Fabricate and test design mods																			
8.4.5	Fabricate production run																			
8.5	Racks																			
8.5.1	Design control wiring																			
8.5.2	Design signal wiring																			
8.5.3	Order parts																			
8.5.4	Assemble prototypes																			
8.6	Software																			
8.7	Prototype Correlator Production																			
8.7.1	Order parts																			
8.7.2	Assemble																			
8.7.3	Test																			
8.7.4	Deliver Prototype Correlator to VLA site																			
8.8	Site Correlator Production																			
8.8.1	First 1/4 correlator																			
8.8.1.1	Determine configuration																			
8.8.1.2	Order parts																			
8.8.1.3	Assemble																			
8.8.1.4	Test																			
8.8.1.5	Deliver 1/4 Correlator to MMA site																			
8.8.2	Second 1/4 correlator																			
8.8.2.1	Order parts																			
8.8.2.2	Assemble																			
8.8.2.3	Test																			
8.8.2.4	Deliver 1/4 Correlator to MMA site																			
8.8.3	Third 1/4 correlator																			
8.8.3.1	Order parts																			
8.8.3.2	Assemble																			
8.8.3.3	Test																			
8.8.3.4	Deliver 1/4 Correlator to MMA site																			
8.8.4	Fourth 1/4 correlator																			
8.8.4.1	Order parts																			
8.8.4.2	Assemble																			
8.8.4.3	Test																			

8.8.4.4	Deliver 1/4 Correlator to MMA site																		
8.9	Continued Support																		
9	Computing																		
9.1	Control Software																		
9.1.1	Test Interferometer Control & Analysis																		
9.1.2	MMA correlator software																		
9.1.3	Multi-antenna & sub-array control	44																	
9.1.4	Operators & Observers interfaces	26																	
9.1.5	Deliver Control Software	10																	
9.1.6	Maintenance																		
9.2	Scheduling																		
9.2.1	Static scheduling system	10																	
9.2.2	Dynamic scheduling simulations																		
9.2.3	Dynamic scheduling prototype	10																	
9.2.4	Dynamic scheduling implementation																		
9.2.5	Initial Operations with Dynamic Scheduling																		
9.3	Proposal Preparation Software																		
9.3.1	Prototype	6																	
9.3.2	Production version	3																	
9.4	Image Pipeline																		
9.4.1	Automated calibration & imaging heuristics																		
9.4.2	Prototype image pipeline	20																	
9.4.3	Parallelization studies and implementation																		
9.4.4	Initial Image Pipeline Operations																		
9.4.5	Production image pipeline																		
9.5	Archiving																		
9.5.1	Prototype distributed archive	10																	
9.5.2	Evaluate storage hardware																		
9.5.3	Production archive	20																	
9.5.4	Data Archive operational																		
9.6	Post-processing																		
9.6.1	Define MMA Data formats	6																	
9.6.2	MMA filler & format conversions	6																	
9.6.3	MMA-specific calibrations	2																	
9.6.4	MMA Post-processing begins																		
9.6.5	Maintenance																		
10	System Integration																		
10.4	Test Interferometer Site Preparation																		
10.4.1	Complete Office and Lab Space Preparation																		
10.4.2	Cabling																		
10.4.3	Test Interferometer Site Complete																		
10.10.4	Prototype Antenna Outfitting																		
10.10.4.1	Cabling																		
10.10.4.2	Instrumentation																		
10.10.4.3	Eval. Rcvr. #1 / Ant. #1 Integration																		
10.10.4.4	Antenna #1 Outfitting Complete																		
10.10.5	Integration Holography System/Antenna																		
10.10.6	Integration Metrology/Antenna																		
10.10.7	Antenna #1 Integration & Testing																		

10.10.8	Prot. Rcvr. Test & Evaluation																			
10.10.9	Antenna #2 Outfitting																			
10.10.9.1	Cabling																			
10.10.9.2	Instrumentation																			
10.10.9.3	Eval. Rcvr. #2 / Ant. #2 Integration																			
10.10.9.4	Antenna #2 Outfitting Complete																			
10.11	Test Interferometer																			
10.11.1	Antenna Evaluation & Characterization		6		\$	59			\$	9	\$	59	\$	9	\$	61				
10.11.1.1	Antenna Verification																			
10.11.1.4	Holography																			
10.11.1.5	Beam and Sidelobes																			
10.11.1.6	Gain vs. Elevation: Spillover Temp																			
10.11.1.7	Effect of Sun in & Near the Beam																			
10.11.2	Engineering Recommendations re Prod. Ant.																			
10.11.3	Revise Interface Specifications		3		\$	29			\$	4	\$	29	\$	5	\$	31				
10.11.5	Operations Personnel Training																			
10.11.5.1	Recruit Initial Chile Ops Staff	6			48	\$	283		\$	283		\$	-	\$	-	\$	-			
10.11.5.2	Array Operations																			
10.11.5.3	Engineering Maintenance																			
10.11.5.4	Scientific Support & Analysis																			
10.12.2	Relocate Ops Staff to Chile																			
10.8.4.6	Start On-site Operations																			
10.12	Disassemble Test Interferometer																			
10.12.1	Prepare & Ship Antenna #1, #2																			
10.12.3	Restore Facilities at VLA Site																			
10.13	On Site System Integration				36	\$	176		\$	176		\$	-	\$	-	\$	-			
11	Calibration and Imaging																			
11.1	Radiometric Phase Design & Prototype																			
11.1.1	Complete 183GHz Phase Mon Prototype																			
11.1.2	Demo 183 GHz Phase Monitor Radiometer on-Site																			
11.1.3	Design Refinement																			
11.1.4	Release Phase Mon Radiometer for manufacture																			
11.2	Production Fab of Phase Monitor Radiometer		10	12	\$	156	\$	684		\$	93	\$	201	\$	747	\$	211	\$	784	
11.2.1	Contract Subassembly Fabrication																			
11.2.1.1	Radiometer & Local Oscillator																			
11.2.1.2	Spectrometer																			
11.2.1.3	Feed, Window, lens, instrumentation																			
11.2.1.4	M/C Interface																			
11.2.2	Assembly & Test																			
11.2.3	Deliver Production Radiometers																			
11.2.4	Integration in Receiver Package																			
11.2.5	Verification on-Site																			
11.3	Production Fabrication of Dual-load Amp Cal Sys				12	\$	59	\$	163		\$	25	\$	50	\$	197	\$	53	\$	207
11.3.1	Design Refinement																			
11.3.2	Release Phase Mon Radiometer for manufacture																			
11.3.3	Contract Subassembly																			
11.3.3.1	Machining																			
11.3.3.2	Load Fabrication																			
11.3.3.3	Motors, Servo																			
11.3.3.4	M/C Interface																			
11.3.4	Assembly & Test																			

11.3.5	Integration on Production Antennas												
11.4	Imaging Studies & Project Support	72				\$ 585		\$ 585		\$ -	\$ -	\$ -	\$ -
11.5	Imaging Algorithm Development	8	4			\$ 100				\$ 15	\$ 100	\$ 16	\$ 105
	TOTALS					\$ 11,580	\$ 33,369	\$ 1,472	\$ 4,840	\$ 7,161	\$ 38,637	\$ 7,523	\$ 40,593

Millimeter Array Construction 2004

WBS	Name	Scientists Work- Months	Programmers Work-Months	Engineers Work- Months	Technicians Work- Months	Personnel Cost	Materials and Supplies	Transfer to Operations	Adjustment to Scope	Contingency	Sum Cost	Inflated Contingency	Inflated Sum
1	Administration												
1.1	Project Management	72			48	\$ 819		\$ 215		\$ 91	\$ 605	\$ 98	\$ 651
1.1.1	Management, Planning, and Oversight						\$ 700			\$ 105	\$ 700	\$ 113	\$ 754
1.1.2	Business Operations						\$ 100			\$ 15	\$ 100	\$ 16	\$ 108
1.1.3	Chilean Operations						\$ 50			\$ 8	\$ 50	\$ 8	\$ 54
1.1.4	Safety and Health												
1.1.5	Personnel												
1.1.6	Project Science Office												
1.1.7	AUI Management						\$ 350			\$ -	\$ 350	\$ -	\$ 377
1.2	Engineering			24	12	\$ 293	\$ 20			\$ 47	\$ 313	\$ 50	\$ 337
1.2.1	System Engineering--Phase II												
1.2.2	Documentation System												
1.2.3	Production Engineering												
1.3	US Facilities												
1.3.1	CDL Permanent Facilities						\$ 600			\$ -	\$ 600	\$ -	\$ 646
1.3.2	Manufacturing Facilities						\$ 100			\$ 15	\$ 100	\$ 16	\$ 108
1.3.3	Common Infrastructure						\$ 200			\$ 30	\$ 200	\$ 32	\$ 215
2	Site Development			12		\$ 117	\$ 50			\$ 28	\$ 167	\$ 30	\$ 180
2.1	Review Legalities Regarding Array and OSF Sites												
2.2	Maintain Mining claims						\$ 25			\$ -	\$ 25	\$ -	\$ 27
2.3	Contract A&E Studies												
2.4	Hire Construction Manager for Chile												
2.5	Array Site												
2.5.1	Prepare Site Development Bid Packages												
2.5.1.1	Prepare Package for Array Site												
2.5.1.2	Review Bid Packages												
2.5.1.3	Bid Civil Works Construction												
2.5.2	Evaluate Array Site Bid Response												
2.5.2.1	Review Bids												
2.5.2.2	Recommend Contractors												
2.5.2.3	Award Array Site Contracts												
2.5.3	Contract Array Site Civil Works												
2.5.3.1	Array Site												
2.5.3.2	Inspect Completed Site Constr												
2.5.3.3	Accept Site Facility												
2.6	Operations Support Facility												
2.6.1	Prepare OSF Bid Packages												
2.6.1.1	Prepare Package for OSF												
2.6.1.2	Review Bid Packages												
2.6.1.3	Bid Civil Works Construction												
2.6.2	Evaluate OSF Bid Response												
2.6.2.1	Review Bids												
2.6.2.2	Recommend Contractors												
2.6.2.3	Award Contracts												

3.19	Accept Antenna #7 at OSF			3	\$ 29	\$ 2,832			\$ 854	\$ 2,861	\$ 920	\$ 3,081
3.20	Prepare Antenna #7											
3.20.1	Outfit & Verify Ant #7 at OSF											
3.20.2	Move, Install & Verify Ant #7 on Site											
3.21	Accept Antenna #8 at OSF			3	\$ 29	\$ 2,832			\$ 854	\$ 2,861	\$ 920	\$ 3,081
3.22	Prepare Antenna #8											
3.22.1	Outfit & Verify Ant #8 at OSF											
3.22.2	Move, Install & Verify Ant #8 on Site											
3.23	Accept Antenna #9 at OSF			3	\$ 29	\$ 2,832			\$ 854	\$ 2,861	\$ 920	\$ 3,081
3.24	Prepare Antenna #9											
3.24.1	Outfit & Verify Ant #9 at OSF											
3.24.2	Move, Install & Verify Ant #9 on Site											
3.25	Accept Antenna #10 at OSF			3	\$ 29	\$ 2,832			\$ 854	\$ 2,861	\$ 920	\$ 3,081
3.26	Prepare Antenna #10											
3.26.1	Outfit & Verify Ant #10 at OSF											
3.26.2	Move, Install and Verify Ant #10 on Site											
3.27	Accept Antenna #11 at OSF			3	\$ 29	\$ 2,832			\$ 854	\$ 2,861	\$ 920	\$ 3,081
3.28	Prepare Antenna #11											
3.28.1	Outfit & Verify Ant #11 at OSF											
3.28.2	Move, Install & Verify Ant #11 on Site											
3.29	Accept Antenna #12 at OSF			3	\$ 29	\$ 2,832			\$ 854	\$ 2,861	\$ 920	\$ 3,081
3.30	Prepare Antenna #12											
3.30.1	Outfit & Verify Ant #12 at OSF											
3.30.2	Move, Install & Verify Ant #12 on Site											
3.31	Accept Antenna #13 at OSF			3	\$ 29	\$ 2,832			\$ 854	\$ 2,861	\$ 920	\$ 3,081
3.32	Prepare Antenna #13											
3.32.1	Outfit & Verify Ant #13 at OSF											
3.32.2	Move, Install & Verify Ant #13 on Site											
3.33	Accept Antenna #14 at OSF			3	\$ 29	\$ 2,832			\$ 854	\$ 2,861	\$ 920	\$ 3,081
3.34	Prepare Antenna #14											
3.34.1	Outfit & Verify Ant #14 at OSF											
3.34.2	Move, Install & Verify Ant #14 on Site											
3.35	Accept Antenna #15 at OSF			3	\$ 29	\$ 2,832			\$ 854	\$ 2,861	\$ 920	\$ 3,081
3.36	Prepare Antenna #15											
3.36.1	Outfit & Verify Ant #15 at OSF											
3.36.2	Move, Install & Verify Ant #15 on Site											
3.37	Accept Antenna #16 at OSF											
3.38	Prepare Antenna #16											
3.38.1	Outfit & Verify Ant #16 at OSF											
3.38.2	Move, Install & Verify Ant #16 on Site											
3.39	Accept Antenna #17 at OSF											
3.40	Prepare Antenna #17											
3.40.1	Outfit & Verify Ant #17 at OSF											
3.40.2	Move, Install & Verify Ant #17 on Site											
3.41	Accept Antenna #18 at OSF											
3.42	Prepare Antenna #18											
3.42.1	Outfit & Verify Ant #18 at OSF											
3.42.2	Move, Install & Verify Ant #18 on Site											
3.43	Accept Antenna #19 at OSF											
3.44	Prepare Antenna #19											
3.44.1	Outfit & Verify Ant #19 at OSF											
3.44.2	Move, Install & Verify Ant #19 on Site											
3.45	Accept Antenna #20 at OSF											

3.72.1	Outfit & Verify Ant #33 at OSF																						
3.72.2	Move, Install and Verify Ant #33 on Site																						
3.73	Accept Antenna #34 at OSF																						
3.74	Prepare Antenna #34																						
3.74.1	Outfit & Verify Ant #34 at OSF																						
3.74.2	Move, Install and Verify Ant #34 on Site																						
3.75	Accept Antenna #35 at OSF																						
3.76	Prepare Antenna #35																						
3.76.1	Outfit & Verify Ant #35 at OSF																						
3.76.2	Move, Install & Verify Ant #35 on Site																						
3.77	Accept Antenna #36 at OSF																						
3.78	Prepare Antenna #36																						
3.78.1	Outfit & Verify Ant #36 at OSF																						
3.78.2	Move, Install & Verify Ant #36 on Site																						
3.79	Prepare Antenna #1																						
3.79.1	Antenna #1 Reassembled at OSF																						
3.79.2	Outfit & Verify Ant #1 at OSF																						
3.79.3	Move, Install & Verify Ant #1 on Site																						
3.80	Prepare Antenna #2																						
3.80.1	Antenna #2 Reassembled at OSF																						
3.80.2	Outfit & Verify Ant #2 at OSF																						
3.80.3	Move, Install & Verify Ant #2 on Site																						
3.81	Antenna Transporter																						
3.81.1	Contract for Transporter #1 move to site																						
3.81.2	Contract for Transporters #2, #3																						
3.81.3	Accept Transporters #2, #3 at OSF																						
4	Receivers																						
4.1	Receiver Package																						
4.1.1	Prototype Production Receiver Cryogenics																						
4.1.1.1	CDR: Cryogenics Development																						
4.1.1.2	Construct & test prototype cryogenics																						
4.1.1.3	Deliver Prototype Cryogenics Subsystem																						
4.1.2	Prototype Production Receiver Package																						
4.1.2.1	Prototype Receiver Package Integration																						
4.1.2.2	Prot. Rcvr. Pckg Lab Test & Evaluation																						
4.1.2.3	Complete Prototype MMA Receiver Package																						
4.1.3	MMA Rcvr Pckg Design Refinement																						
4.1.4	Documentation																						
4.1.5	Release MMA Receiver Pckg for manufacture																						
4.1.6	Contract for Receiver Pckg Subassemblies																						
4.1.6.1	Machine Dewars																						
4.1.6.2	Fabricate Cryogenics subsystems			6		30	\$	146	\$	50		\$	22	\$	30	\$	174	\$	33	\$	188		
4.1.6.3	Fabricate windows, IR filters, etc			6		30	\$	205	\$	100		\$	46	\$	84	\$	369	\$	91	\$	398		
4.1.7	Accept Receiver Pckg Subassemblies																						
4.1.7.1	Subassemblies #1-6																						
4.1.7.2	Subassemblies #7-16																						
4.1.7.3	Subassemblies #17-26																						
4.1.7.4	Subassemblies #27-36																						
4.1.7.5	Subassemblies #37-40																						

4.1.8	Fab Rcvr Pckg Instrumentation & Electronics		6	6	12	\$ 169	\$ 100		\$ 30	\$ 46	\$ 239	\$ 50	\$ 257
4.1.9	Fabricate Receiver Inserts			18	30	\$ 322	\$ 100		\$ 47	\$ 64	\$ 375	\$ 69	\$ 404
4.1.10	Assemble Receiver Package												
4.1.10.1	Integrate Rcvr Instrumentation & subassy			12	48	\$ 351	\$ 80		\$ 48	\$ 62	\$ 383	\$ 67	\$ 413
4.1.10.2	Deliver Receiver Package #1-6												
4.1.10.3	Deliver Receiver Package #7-16												
4.1.10.4	Deliver Receiver Package #17-26												
4.1.10.5	Deliver Receiver Package #27-36												
4.1.10.6	Deliver Receiver Package #37-40												
4.2	SIS Receiver Modules												
4.2.1	211-275 GHz Module												
4.2.1.1	SIS Mixer												
4.2.1.1.1	Design, Fab and Test Mixer Design												
4.2.1.1.2	Deliver Production Design												
4.2.1.1.3	Fabricate Production Mixers												
4.2.1.2	Design & Verify Optics												
4.2.1.3	Design Module												
4.2.1.4	Contract Fabrication				4	\$ 20	\$ 25		\$ 5	\$ 9	\$ 40	\$ 10	\$ 43
4.2.1.4.1	Machine Mixer Blocks, Feed, WG, Lenses												
4.2.1.4.2	Assemble Modules												
4.2.1.5	Install SIS Mixer & Test Modules			18	36	\$ 351	\$ 30		\$ 42	\$ 49	\$ 339	\$ 53	\$ 365
4.2.1.6	Deliver 211-275 GHz Receiver Modules												
4.2.1.6.1	Deliver Modules #1-7												
4.2.1.6.2	Deliver Modules #8-26												
4.2.1.6.3	Deliver Modules #27-40												
4.2.2	602-720 GHz Module												
4.2.2.1	SIS Mixer												
4.2.2.1.1	Design, Fabricate and Test Mixer Design												
4.2.2.1.2	Deliver Production Design												
4.2.2.1.3	Fabricate Production Mixers												
4.2.2.2	Design & Verify Optics												
4.2.2.3	Design Module												
4.2.2.4	Contract Fabrication				4	\$ 20	\$ 25		\$ 45	\$ -	\$ -	\$ -	\$ -
4.2.2.4.1	Machine Mixer Blocks, Feed, WG, Lenses												
4.2.2.4.2	Assemble Modules												
4.2.2.5	Install SIS Mixer and Test Modules			18	36	\$ 351	\$ 30		\$ 381	\$ -	\$ -	\$ -	\$ -
4.2.2.6	Deliver 602-720 GHz Receiver Modules												
4.2.2.6.1	Deliver Modules #1-7												
4.2.2.6.2	Deliver Modules #8-26												
4.2.2.6.3	Deliver Modules #27-40												
4.2.3	275-370 GHz Receiver Module												
4.2.3.1	SIS Mixer												
4.2.3.1.1	Design, Fabricate and Test Mixer Design												
4.2.3.1.2	Deliver Production Design												
4.2.3.1.3	Fabricate Production Mixers												
4.2.3.2	Design & Verify Optics												
4.2.3.3	Design Module												
4.2.3.4	Contract Fabrication				4	\$ 20	\$ 100		\$ 11	\$ 30	\$ 108	\$ 32	\$ 17
4.2.3.4.1	Machine Mixer Blocks, Feed, WG, Lenses												
4.2.3.4.2	Assemble Modules												

4.2.3.5	Install SIS Mixer and Test Modules		18	36	\$ 351	\$ 40		\$ 4	\$ 63	\$ 387	\$ 68	\$ 416
4.2.3.6	Deliver 275-370 GHz Receiver Module											
4.2.3.6.1	Deliver Modules #1-5											
4.2.3.6.2	Deliver Modules #6-30											
4.2.3.6.3	Deliver Modules #30-40											
4.2.4	91-119 GHz Receiver Module											
4.2.4.1	SIS Mixer											
4.2.4.1.1	Design, Fabricate & Test Mixer Design											
4.2.4.1.2	Deliver Production Design											
4.2.4.1.3	Fabricate Production Mixers											
4.2.4.2	Design & Verify Optics											
4.2.4.3	Design Module											
4.2.4.4	Contract Fabrication			4	\$ 20	\$ 100		\$ 11	\$ 30	\$ 108	\$ 32	\$ 117
4.2.4.4.1	Machine Mixer Blocks, Feed, WG, Lenses											
4.2.4.4.2	Assemble Modules											
4.2.4.5	Install SIS Mixer and Test Modules		18	36	\$ 351	\$ 40		\$ 4	\$ 63	\$ 387	\$ 68	\$ 416
4.2.4.6	Deliver 91-119 GHz Receiver Modules											
4.2.4.6.1	Deliver Modules #1-5											
4.2.4.6.2	Deliver Modules #6-30											
4.2.4.6.3	Deliver Modules # 31-40											
4.2.5	163-211 GHz Receiver Module		36	24	\$ 468	\$ 100		\$ 11	\$ 97	\$ 557	\$ 104	\$ 600
4.2.5.1	SIS Mixer							\$ -	\$ -	\$ -	\$ -	\$ -
4.2.5.1.1	Design, Fabricate & Test Mixer Design											
4.2.5.1.2	Deliver Production Design											
4.2.5.1.3	Fabricate Production Mixers											
4.2.5.2	Design & Verify Optics											
4.2.5.3	Design Module											
4.2.5.4	Contract Fabrication			4	\$ 20	\$ 100		\$ 11	\$ 30	\$ 108	\$ 32	\$ 117
4.2.5.4.1	Machine Mixer Blocks, Feed, WG, Lenses											
4.2.5.4.2	Assemble Modules		6	12	\$ 117	\$ 20		\$ 2	\$ 23	\$ 135	\$ 25	\$ 145
4.2.5.5	Install SIS Mixer and Test											
4.2.5.6	Deliver 163-211 GHz Receiver Modules											
4.2.5.6.1	Deliver Modules #1-5											
4.2.5.6.2	Deliver Modules #6-30											
4.2.5.6.3	Deliver Modules #31-40											
4.2.6	385-500 GHz Receiver Module		36	24	\$ 468	\$ 100		\$ 568	\$ -	\$ -	\$ -	\$ -
4.2.6.1	SIS Mixer							\$ -	\$ -	\$ -	\$ -	\$ -
4.2.6.1.1	Design, Fabricate & Test Mixer Design											
4.2.6.1.2	Deliver Production Design											
4.2.6.1.3	Fabricate Production Mixers											
4.2.6.2	Design and Verify Optics											
4.2.6.3	Design Module											
4.2.6.4	Contract Fabrication			4	\$ 20	\$ 100		\$ 120	\$ -	\$ -	\$ -	\$ -
4.2.6.4.1	Machine Mixer Blocks, Feed, WG, Lenses											
4.2.6.4.2	Assemble Modules											
4.2.6.5	Install SIS Mixer and Test		6	12	\$ 117	\$ 20		\$ 137	\$ -	\$ -	\$ -	\$ -
4.2.6.6	Deliver 385-500 GHz Receiver Modules											
4.2.6.6.1	Deliver Modules #1-5											
4.2.6.6.2	Deliver Modules #6-30											
4.2.6.6.3	Deliver Modules #31-40											

4.2.7	125-163 GHz Receiver Module				6	6	\$ 88	\$ 400		\$ 49	\$ 119	\$ 439	\$ 128	\$ 473
4.2.7.1	SIS Mixer											\$ -	\$ -	\$ -
4.2.7.1.1	Design, Fabricate & Test Mixer Design													
4.2.7.1.2	Deliver Production Design													
4.2.7.1.3	Fabricate Production Mixers													
4.2.7.2	Design & Verify Optics													
4.2.7.3	Design Module													
4.2.7.4	Contract Fabrication													
4.2.7.4.1	Machine Mixer Blocks, Feed, WG, Lenses													
4.2.7.4.2	Assemble Modules					2	\$ 10	\$ 50		\$ 7	\$ 14	\$ 53	\$ 15	\$ 57
4.2.7.5	Install SIS Mixer and Test													
4.2.7.6	Deliver 125-163 GHz Receiver Modules													
4.2.7.6.1	Deliver 125-163 GHz Modules #1-5													
4.2.7.6.2	Deliver 125-163 GHz Modules #6-30													
4.2.7.6.3	Deliver 125-163 GHz Modules #31-40													
4.3	HFET Receiver Modules				6	12	\$ 117	\$ 50		\$ 6	\$ 24	\$ 161	\$ 26	\$ 174
4.3.1	Contract for HFET Wafer													
4.3.2	Receive Diced HFET Wafer													
4.3.3	33-45 GHz Module													
4.3.3.1	Design Module													
4.3.3.2	Design & Verify Optics													
4.3.3.3	Contract Fabrication													
4.3.3.3.1	Machine Blocks, Feed, WG, Lenses													
4.3.3.3.2	Assemble Modules													
4.3.3.3.3	Flip-in Mirror													
4.3.4	Install HFET & Test Modules													
4.3.5	Deliver 33-45 GHz Receiver Modules													
4.3.5.1	Deliver Modules #1-20													
4.3.5.2	Deliver Modules #21-40													
4.3.6	67-95 GHz Module													
4.3.6.1	Design Amplifier													
4.3.6.2	Design Module													
4.3.6.3	Design & Verify Optics													
4.3.6.4	Contract Fabrication													
4.3.6.4.1	Machine Blocks, Feed, WG, Lenses													
4.3.6.4.2	Assemble Modules													
4.3.6.5	Install HFET & Test Modules													
4.3.6.6	Deliver 67-95 GHz Receiver Modules													
4.3.6.6.1	Deliver Modules 67-95GHz #1-20													
4.3.6.6.2	Deliver Modules 67-95GHz #21-40													
5	LO System													
5.1	LO Reference: Prototype Systems													
5.1.1	Deliver: Bench Prototype													
5.1.2	Testing and Design Refinement													
5.1.3	Procure/Fab Field Prototypes													
5.1.4	Deliver: LO Ref Field Prototypes													
5.1.5	Field Prototype testing and Design Refinement													
5.1.6	Preproduction Review													

5.1.7	Final Documentation and Design Modifications														
5.1.8	Release for Manufacture														
5.2	LO Reference: Production System	12	48	\$	351			\$	53	\$	351	\$	57	\$	378
5.1.1	Production test and lab equipment														
5.1.2	H-maser Frequency Standard (& Rb)														
5.1.3	8 GHz PL Oscillator & Distributor				\$	1		\$	0	\$	0	\$	1	\$	0
5.1.4	10 GHz PL Oscillator & Distributor				\$	1		\$	0	\$	0	\$	1	\$	0
5.1.5	12 GHz PL Oscillator & Distributor				\$	1		\$	0	\$	0	\$	1	\$	0
5.1.6	14 GHz PL Oscillator & Distributor				\$	1		\$	0	\$	0	\$	1	\$	0
5.1.7	3.2-5.2 GHz Synthesizer				\$	8		\$	1	\$	1	\$	7	\$	1
5.1.8	3.2 -5.2 GHz PLO and Fringe Generator				\$	160		\$	18	\$	21	\$	142	\$	23
5.1.9	Sampler Clock 4 GHz PL Osc & Distributor				\$	1		\$	0	\$	0	\$	1	\$	0
5.1.10	LO Ref Generator				\$	2		\$	0	\$	0	\$	2	\$	0
5.1.11	LO Ref Distributor - Control Bldg				\$	1		\$	0	\$	0	\$	1	\$	0
5.1.12	Microwave Round-trip Phase Measurement				\$	60		\$	7	\$	8	\$	53	\$	9
5.1.13	10-15 GHz Frequency Synthesizer				\$	100		\$	11	\$	13	\$	89	\$	14
5.1.14	First LO Fringe Generator				\$	20		\$	2	\$	3	\$	18	\$	3
5.1.15	16 GHz PL Oscillator				\$	40		\$	4	\$	5	\$	36	\$	6
5.1.16	26 GHz PL Oscillator				\$	40		\$	4	\$	5	\$	36	\$	6
5.1.17	LO Ref Distributor - Antenna				\$	20		\$	2	\$	3	\$	18	\$	3
5.1.18	VXCO Clean-up Loop				\$	20		\$	2	\$	3	\$	18	\$	3
5.1.19	Power supply module				\$	60		\$	7	\$	8	\$	53	\$	9
5.1.20	Bins / Racks (assemble and test)				\$	16		\$	2	\$	2	\$	14	\$	2
5.3	Millimeter LO Drivers														
5.3.1	Design and System Integration	3		\$	29			\$	4	\$	29	\$	5	\$	31
5.3.2	72-95 GHz Source		3	\$	15			\$	2	\$	2	\$	13	\$	2
5.3.2.1	Contract Procurement and Fabrication														
5.3.2.1.1	YIG-tuned Oscillator														
5.3.2.1.2	18.00 - 23.75 GHz 10 db Amplifier														
5.3.2.1.3	18.00 - 23.75 GHz x2 Multiplier														
5.3.2.1.4	36.0 - 47.5 GHz 10 db Amplifier														
5.3.2.1.5	36.0 - 47.5 GHz x2 Multiplier														
5.3.2.1.6	Mount and Tuning circuitry														
5.3.2.2	Assembly and Test														
5.3.2.3	Deliver 72 - 95 GHz LO Sources														
5.3.2.3.1	Deliver Modules #1-6														
5.3.2.3.2	Deliver Modules #7-24														
5.3.2.3.3	Deliver Modules #25-40														
5.3.3	100-120 GHz Source			3	\$	15		\$	15	\$	-	\$	-	\$	-
5.3.3.1	Contract Procurement and Fabrication														
5.3.3.1.1	YIG-tuned Oscillator														
5.3.3.1.2	25.00 - 30.00 GHz 10 db Amplifier														
5.3.3.1.3	15.00 - 30.00 GHz x2 Multiplier														
5.3.3.1.4	50.0 - 60.0 GHz 10 db Amplifier														
5.3.3.1.5	50-60 GHz x2 Multiplier														
5.3.3.1.6	Mount and Tuning circuitry														
5.3.3.2	Assembly and Test														
5.3.3.3	Deliver 100 - 120 GHz LO Sources														
5.3.3.3.1	Deliver Modules #1-3														
5.3.3.3.2	Deliver Modules #4-21														
5.3.3.3.3	Deliver Modules #22-40														

5.3.4	87 - 108 GHz Source			6	8	\$ 98	\$ 240		\$ 38	\$ 75	\$ 300	\$ 81	\$ 323
5.3.4.1	Contract Procurement and Fabrication												
5.3.4.1.1	YIG-tuned Oscillator												
5.3.4.1.2	21.75-27.00 GHz 10 db Amplifier												
5.3.4.1.3	21.75-27.00 GHz x2 Multiplier												
5.3.4.1.4	43.5-54.0 GHz 10 db Amplifier												
5.3.4.1.5	43.5-54.0 GHz x2 Multiplier												
5.3.4.1.6	Mount and Tuning Circuitry												
5.3.4.2	Assembly and Test												
5.3.4.3	Deliver 87 - 108 GHz LO Sources												
5.3.4.3.1	Deliver Modules #1-6												
5.3.4.3.2	Deliver Modules #7-20												
5.3.4.3.3	Deliver Modules #21-35												
5.3.4.3.4	Deliver Modules #36-40												
5.3.5	65 - 85 GHz Source			6	8	\$ 98	\$ 240		\$ 38	\$ 75	\$ 300	\$ 81	\$ 323
5.3.5.1	Contract Procurement and Fabrication												
5.3.5.1.1	YIG-tuned Oscillator												
5.3.5.1.2	16.25-21.25 GHz 10 db Amplifier												
5.3.5.1.3	16.25-21.25 GHz x2 Multiplier												
5.3.5.1.4	32.5-42.5 GHz 10 db Amplifier												
5.3.5.1.5	32.5-42.5 GHz x2 Multiplier												
5.3.5.1.6	Mount and Tuning Circuitry												
5.3.5.2	Assembly and Test												
5.3.5.3	Deliver 65 - 85 GHz LO Sources												
5.3.5.3.1	Deliver Modules #1-6												
5.3.5.3.2	Deliver Modules #7-20												
5.3.5.3.3	Deliver Modules #21-35												
5.3.5.3.4	Deliver Modules #36-40												
5.4	Millimeter LO Multiplier Chains												
5.4.1	Design and System Integration			2		\$ 20			\$ 3	\$ 20	\$ 3	\$ 21	
5.4.2	211 - 275 GHz Receiver LO			3	18	\$ 117	\$ 50		\$ 19	\$ 27	\$ 148	\$ 29	\$ 160
5.4.2.1	Contract Fabrication												
5.4.2.1.1	X3 Diode for 72-95 GHz Source												
5.4.2.1.2	Machine Mount												
5.4.2.1.3	Bias and Control circuits												
5.4.2.2	Assemble Multiplier and Test												
5.4.2.3	Integrate Source and Multiplier; test												
5.4.2.4	Deliver 211-275 GHz Rcvr LO Modules												
5.4.2.4.1	Deliver Modules #1-3												
5.4.2.4.2	Deliver Modules #4-21												
5.4.2.4.3	Deliver Modules #22-40												
5.4.3	602 - 720 GHz Receiver LO			3	18	\$ 117	\$ 50		\$ 167	\$ -	\$ -	\$ -	\$ -
5.4.3.1	Contract Fabrication												
5.4.3.1.1	X2 Diode for 100-120 GHz Source												
5.4.3.1.2	X3 Diode for 200-240 GHz Input												
5.4.3.1.3	Machine Mount												
5.4.3.1.4	Bias and Control circuits												
5.4.3.2	Assemble Multipliers and Test												
5.4.3.3	Integrate Source and Multipliers; test												

5.4.3.4	Deliver 602-720 GHz Rcvr LO Modules																			
5.4.3.4.1	Deliver Modules #1-6																			
5.4.3.4.2	Deliver Modules #7-18																			
5.4.3.4.3	Deliver Modules #19-34																			
5.4.3.4.4	Deliver Modules #35-40																			
5.4.4	275 - 370 GHz Receiver LO		3	18	\$	117	\$	50		\$	19	\$	27	\$	148	\$	29	\$	160	
5.4.4.1	Contract Fabrication																			
5.4.4.1.1	X2 Diode for 72-95 GHz Source																			
5.4.4.1.2	X2 Diode for 144-190 GHz Input																			
5.4.4.1.3	Machine Mount																			
5.4.4.1.4	Bias and Control Circuits																			
5.4.4.2	Assemble Multipliers and Test																			
5.4.4.3	Integrate Source and Multipliers; test																			
5.4.4.4	Deliver 275-370 GHz Rcvr LO Modules																			
5.4.4.4.1	Deliver Modules #1-6																			
5.4.4.4.2	Deliver Modules #7-27																			
5.4.4.4.3	Deliver Modules #28-40																			
5.4.5	163 - 211 GHz Receiver LO		3	18	\$	117	\$	50		\$	19	\$	27	\$	148	\$	29	\$	160	
5.4.5.1	Contract Fabrication																			
5.4.5.1.1	X2 Diode for 87-108 GHz Source																			
5.4.5.1.2	Machine Mount																			
5.4.5.1.3	Bias and Control Circuits																			
5.4.5.2	Assemble Multiplier and Test																			
5.4.5.3	Integrate Source and Multiplier; test																			
5.4.5.4	Deliver 163 - 211 GHz Rcvr LO Modules																			
5.4.5.4.1	Deliver Modules #1-6																			
5.4.5.4.2	Deliver Modules #7-24																			
5.4.5.4.3	Deliver Modules #25-40																			
5.4.6	385 - 500 GHz Receiver LO		3	18	\$	117	\$	50		\$	19	\$	27	\$	148	\$	29	\$	160	
5.4.6.1	Contract Fabrication																			
5.4.6.1.1	X3 Diode for 65-85 GHz Source																			
5.4.6.1.2	X2 Diode for 130-170 GHz Input																			
5.4.6.1.3	Machine Mount																			
5.4.6.1.4	Bias and Control Circuits																			
5.4.6.2	Assemble Multiplier and test																			
5.4.6.3	Integrate source and Multiplier; test																			
5.4.6.4	Deliver 385-500 GHz Rcvr LO Modules																			
5.4.6.4.1	Deliver Modules #1-6																			
5.4.6.4.2	Deliver Modules #7-24																			
5.4.6.4.3	Deliver Modules #25-40																			
5.4.7	125 - 163 GHz Receiver LO		6	24	\$	176	\$	75		\$	28	\$	40	\$	223	\$	44	\$	240	
5.4.7.1	Contract Fabrication																			
5.4.7.1.1	X2 Diode for 65 - 85 GHz Source																			
5.4.7.1.2	Machine Mount																			
5.4.7.1.3	Bias and Control Circuits																			
5.4.7.2	Assemble Multiplier and test																			
5.4.7.3	Integrate Source and Multiplier; test																			
5.4.7.4	Deliver 125-163 GHz Rcvr LO Modules																			
5.4.7.4.1	Deliver Modules #1-6																			

8.8.4.4	Deliver 1/4 Correlator to MMA site												
8.9	Continued Support												
9	Computing					\$ 150		\$ 45	\$ 150	\$ 48	\$ 162		
9.1	Control Software												
9.1.1	Test Interferometer Control & Analysis												
9.1.2	MMA correlator software												
9.1.3	Multi-antenna & sub-array control	33			\$ 286		\$ 43	\$ 286	\$ 46	\$ 308			
9.1.4	Operators & Observers interfaces	26			\$ 225		\$ 34	\$ 225	\$ 36	\$ 243			
9.1.5	Deliver Control Software	40			\$ 347		\$ 52	\$ 347	\$ 56	\$ 373			
9.1.6	Maintenance												
9.2	Scheduling												
9.2.1	Static scheduling system	9			\$ 78		\$ 12	\$ 78	\$ 13	\$ 84			
9.2.2	Dynamic scheduling simulations												
9.2.3	Dynamic scheduling prototype	10			\$ 87		\$ 13	\$ 87	\$ 14	\$ 93			
9.2.4	Dynamic scheduling implementation												
9.2.5	Initial Operations with Dynamic Scheduling												
9.3	Proposal Preparation Software												
9.3.1	Prototype	5			\$ 43		\$ 7	\$ 43	\$ 7	\$ 47			
9.3.2	Production version	10			\$ 87		\$ 13	\$ 87	\$ 14	\$ 93			
9.4	Image Pipeline												
9.4.1	Automated calibration & imaging heuristics												
9.4.2	Prototype image pipeline												
9.4.3	Parallelization studies and implementation	12			\$ 104		\$ 16	\$ 104	\$ 17	\$ 112			
9.4.4	Initial Image Pipeline Operations												
9.4.5	Production image pipeline												
9.5	Archiving												
9.5.1	Prototype distributed archive												
9.5.2	Evaluate storage hardware												
9.5.3	Production archive	20			\$ 173		\$ 26	\$ 173	\$ 28	\$ 187			
9.5.4	Data Archive operational												
9.6	Post-processing												
9.6.1	Define MMA Data formats												
9.6.2	MMA filler & format conversions	5			\$ 43		\$ 7	\$ 43	\$ 7	\$ 47			
9.6.3	MMA-specific calibrations	5			\$ 43		\$ 7	\$ 43	\$ 7	\$ 47			
9.6.4	MMA Post-processing begins												
9.6.5	Maintenance	12			\$ 104	\$ 104	\$ -	\$ -	\$ -	\$ -			
10	System Integration												
10.4	Test Interferometer Site Preparation												
10.4.1	Complete Office and Lab Space Preparation												
10.4.2	Cabling												
10.4.3	Test Interferometer Site Complete												
10.10.4	Prototype Antenna Outfitting												
10.10.4.1	Cabling												
10.10.4.2	Instrumentation												
10.10.4.3	Eval. Rcvr. #1 / Ant. #1 Integration												
10.10.4.4	Antenna #1 Outfitting Complete												
10.10.5	Integration Holography System/Antenna												
10.10.6	Integration Metrology/Antenna												
10.10.7	Antenna #1 Integration & Testing												

11.3.5	Integration on Production Antennas												
11.4	Imaging Studies & Project Support	72				\$ 585	\$ 585	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
11.5	Imaging Algorithm Development	8	4			\$ 100		\$ 15	\$ 100	\$ 16	\$ 107		
TOTALS						\$ 12,205	\$ 41,781	\$ 5,455	\$ 2,420	\$ 11,706	\$ 46,110	\$ 12,606	\$ 49,656

Millimeter Array Construction 2005

WBS	Name	Scientists Work-Months	Programmers Work-Months	Engineers Work-Months	Technicians Work-Months	Personnel Cost	Materials and Supplies	Transfer to Operations	Adjustment to Scope	Contingency	Sum Cost	Inflated Contingency	Inflated Sum
1	Administration												
1.1	Project Management	72			48	\$ 819		\$ 215		\$ 91	\$ 605	\$ 100	\$ 667
1.1.1	Management, Planning, and Oversight						\$ 700			\$ 105	\$ 700	\$ 116	\$ 773
1.1.2	Business Operations						\$ 100			\$ 15	\$ 100	\$ 17	\$ 110
1.1.3	Chilean Operations						\$ 50			\$ 8	\$ 50	\$ 8	\$ 55
1.1.4	Safety and Health												
1.1.5	Personnel												
1.1.6	Project Science Office												
1.1.7	AUI Management						\$ 350			\$ -	\$ 350	\$ -	\$ 386
1.2	Engineering			24	12	\$ 293	\$ 20			\$ 47	\$ 313	\$ 52	\$ 345
1.2.1	System Engineering--Phase II												
1.2.2	Documentation System												
1.2.3	Production Engineering												
1.3	US Facilities												
1.3.1	CDL Permanent Facilities						\$ 600			\$ -	\$ 600	\$ -	\$ 662
1.3.2	Manufacturing Facilities						\$ 100			\$ 15	\$ 100	\$ 17	\$ 110
1.3.3	Common Infrastructure						\$ 200			\$ 30	\$ 200	\$ 33	\$ 221
2	Site Development			12		\$ 117	\$ 50			\$ 25	\$ 167	\$ 28	\$ 184
2.1	Review Legalities Regarding Array and OSF Sites												
2.2	Maintain Mining claims						\$ 25			\$ -	\$ 25	\$ -	\$ 28
2.3	Contract A&E Studies												
2.4	Hire Construction Manager for Chile												
2.5	Array Site												
2.5.1	Prepare Site Development Bid Packages												
2.5.1.1	Prepare Package for Array Site												
2.5.1.2	Review Bid Packages												
2.5.1.3	Bid Civil Works Construction												
2.5.2	Evaluate Array Site Bid Response												
2.5.2.1	Review Bids												
2.5.2.2	Recommend Contractors												
2.5.2.3	Award Array Site Contracts												
2.5.3	Contract Array Site Civil Works												
2.5.3.1	Array Site												
2.5.3.2	Inspect Completed Site Constr												
2.5.3.3	Accept Site Facility												
2.6	Operations Support Facility												
2.6.1	Prepare OSF Bid Packages												
2.6.1.1	Prepare Package for OSF												
2.6.1.2	Review Bid Packages												
2.6.1.3	Bid Civil Works Construction												
2.6.2	Evaluate OSF Bid Response												
2.6.2.1	Review Bids												
2.6.2.2	Recommend Contractors												
2.6.2.3	Award Contracts												

2.6.3	Contract OSF Civil Works																			
2.6.3.1	Operations Support Facility																			
2.6.3.2	Inspect Completed OSF Constr																			
2.6.3.3	Accept OSF Facility																			
2.7	OSF/Array Link																			
2.7.1	Prepare OSF/Array Link Bid Package																			
2.7.1.1	Prepare Package for OSF/Array F/O Link																			
2.7.1.2	Review Bid Package																			
2.7.1.3	Bid OSF/Array Link Construction																			
2.7.2	Evaluate Bid Response																			
2.7.2.1	Review Bids																			
2.7.2.2	Recommend Contractors																			
2.7.2.3	Award Contracts																			
2.7.3	Contract Civil Works																			
2.7.3.1	OSF/Array Link																			
2.7.3.2	Inspect Completed OSF/Array Link Constr																			
2.7.3.3	Accept OSF/Array Link																			
2.8	Prepare for Instrument Assembly																			
2.8.1	Equip Array Site																			
2.8.2	Equip Operations Support Facility																			
3	Antenna																			
3.1	Antenna Engineering Support																			
3.3.40	Acceptance Tests Antenna #1																			
3.3.45	Delivery of Antenna #1																			
3.8.10	Sign Transporter Contract																			
3.8.15	Transporter Acceptance tests																			
3.8.20	Deliver/Accept Transporter #1																			
3.7	Procurement of Antenna #2																			
3.7.1	Antenna #2 Contract Supervision																			
3.7.2	Antenna #2 Acceptance tests																			
3.8	Negotiate Production Antenna Contract																			
3.9	Sign Contract for Production Antennas																			
3.10	Antenna Contract Supervision																			
3.11	Accept Antenna #3 at OSF																			
3.12	Prepare Antenna #3																			
3.12.1	Outfit & Verify Ant #3 at OSF																			
3.12.2	Move, Install & Verify Ant #3 on Site																			
3.13	Accept Antenna #4 at OSF																			
3.14	Prepare Antenna #4																			
3.14.1	Outfit & Verify Ant #4 at OSF																			
3.14.2	Move, Install & Verify Ant #4 on Site																			
3.15	Accept Antenna#5 at OSF																			
3.16	Prepare Antenna #5																			
3.16.1	Outfit & Verify Ant #5 at OSF																			
3.16.2	Move, Install & Verify Ant #5 on Site																			
3.17	Accept Antenna#6 at OSF																			
3.18	Prepare Antenna #6																			
3.18.1	Outfit & Verify Ant #6 at OSF																			
3.18.2	Move, Install & Verify Ant #6 on Site																			

3.19	Accept Antenna #7 at OSF			1.5		\$	15				\$	2	\$	15	\$	2	\$	16
3.20	Prepare Antenna #7																	
3.20.1	Outfit & Verify Ant #7 at OSF			2	4	\$	39				\$	6	\$	39	\$	6	\$	43
3.20.2	Move, Install & Verify Ant #7 on Site			1	1	\$	15				\$	2	\$	15	\$	2	\$	16
3.21	Accept Antenna #8 at OSF			1.5		\$	15				\$	2	\$	15	\$	2	\$	16
3.22	Prepare Antenna #8																	
3.22.1	Outfit & Verify Ant #8 at OSF			2	4	\$	39				\$	6	\$	39	\$	6	\$	43
3.22.2	Move, Install & Verify Ant #8 on Site			1	1	\$	15				\$	2	\$	15	\$	2	\$	16
3.23	Accept Antenna #9 at OSF			1.5		\$	15				\$	2	\$	15	\$	2	\$	16
3.24	Prepare Antenna #9																	
3.24.1	Outfit & Verify Ant #9 at OSF			2	4	\$	39				\$	6	\$	39	\$	6	\$	43
3.24.2	Move, Install & Verify Ant #9 on Site			1	1	\$	15				\$	2	\$	15	\$	2	\$	16
3.25	Accept Antenna #10 at OSF			1.5		\$	15				\$	2	\$	15	\$	2	\$	16
3.26	Prepare Antenna #10																	
3.26.1	Outfit & Verify Ant #10 at OSF			2	4	\$	39				\$	6	\$	39	\$	6	\$	43
3.26.2	Move, Install and Verify Ant #10 on Site			1	1	\$	15				\$	2	\$	15	\$	2	\$	16
3.27	Accept Antenna #11 at OSF			1.5		\$	15				\$	2	\$	15	\$	2	\$	16
3.28	Prepare Antenna #11																	
3.28.1	Outfit & Verify Ant #11 at OSF			2	4	\$	39				\$	6	\$	39	\$	6	\$	43
3.28.2	Move, Install & Verify Ant #11 on Site			1	1	\$	15				\$	2	\$	15	\$	2	\$	16
3.29	Accept Antenna #12 at OSF			1.5		\$	15				\$	2	\$	15	\$	2	\$	16
3.30	Prepare Antenna #12																	
3.30.1	Outfit & Verify Ant #12 at OSF			2	4	\$	39				\$	6	\$	39	\$	6	\$	43
3.30.2	Move, Install & Verify Ant #12 on Site			1	1	\$	15				\$	2	\$	15	\$	2	\$	16
3.31	Accept Antenna #13 at OSF			1.5		\$	15				\$	2	\$	15	\$	2	\$	16
3.32	Prepare Antenna #13																	
3.32.1	Outfit & Verify Ant #13 at OSF			2	4	\$	39				\$	6	\$	39	\$	6	\$	43
3.32.2	Move, Install & Verify Ant #13 on Site			1	1	\$	15				\$	2	\$	15	\$	2	\$	16
3.33	Accept Antenna #14 at OSF			1.5		\$	15				\$	2	\$	15	\$	2	\$	16
3.34	Prepare Antenna #14																	
3.34.1	Outfit & Verify Ant #14 at OSF			2	4	\$	39				\$	6	\$	39	\$	6	\$	43
3.34.2	Move, Install & Verify Ant #14 on Site			1	1	\$	15				\$	2	\$	15	\$	2	\$	16
3.35	Accept Antenna #15 at OSF			1.5		\$	15				\$	2	\$	15	\$	2	\$	16
3.36	Prepare Antenna #15																	
3.36.1	Outfit & Verify Ant #15 at OSF			2	4	\$	39				\$	6	\$	39	\$	6	\$	43
3.36.2	Move, Install & Verify Ant #15 on Site			1	1	\$	15				\$	2	\$	15	\$	2	\$	16
3.37	Accept Antenna #16 at OSF			3		\$	29	\$	2,832		\$	854	\$	2,861	\$	943	\$	3,158
3.38	Prepare Antenna #16																	
3.38.1	Outfit & Verify Ant #16 at OSF			2	4	\$	39				\$	6	\$	39	\$	6	\$	43
3.38.2	Move, Install & Verify Ant #16 on Site			1	1	\$	15				\$	2	\$	15	\$	2	\$	16
3.39	Accept Antenna #17 at OSF			3		\$	29	\$	2,832		\$	854	\$	2,861	\$	943	\$	3,158
3.40	Prepare Antenna #17																	
3.40.1	Outfit & Verify Ant #17 at OSF			2	4	\$	39				\$	6	\$	39	\$	6	\$	43
3.40.2	Move, Install & Verify Ant #17 on Site			1	1	\$	15				\$	2	\$	15	\$	2	\$	16
3.41	Accept Antenna #18 at OSF			3		\$	29	\$	2,832		\$	854	\$	2,861	\$	943	\$	3,158
3.42	Prepare Antenna #18																	
3.42.1	Outfit & Verify Ant #18 at OSF			2	4	\$	39				\$	6	\$	39	\$	6	\$	43
3.42.2	Move, Install & Verify Ant #18 on Site			1	1	\$	15				\$	2	\$	15	\$	2	\$	16
3.43	Accept Antenna #19 at OSF			3		\$	29	\$	2,832		\$	854	\$	2,861	\$	943	\$	3,158
3.44	Prepare Antenna #19																	
3.44.1	Outfit & Verify Ant #19 at OSF			2	4	\$	39				\$	6	\$	39	\$	6	\$	43
3.44.2	Move, Install & Verify Ant #19 on Site			1	1	\$	15				\$	2	\$	15	\$	2	\$	16
3.45	Accept Antenna #20 at OSF			3		\$	29	\$	2,832		\$	854	\$	2,861	\$	943	\$	3,158

3.46	Prepare Antenna #20																	
3.46.1	Outfit & Verify Ant #20 at OSF																	
3.46.2	Move, Install & Verify Ant #20 on Site																	
3.47	Accept Antenna #21 at OSF		3		\$	29	\$	2,832			\$	854	\$	2,861	\$	943	\$	3,158
3.48	Prepare Antenna #21																	
3.48.1	Outfit & Verify Ant #21 at OSF																	
3.48.2	Move, Install & Verify Ant #21 on Site																	
3.49	Accept Antenna #22 at OSF		3		\$	29	\$	2,832			\$	854	\$	2,861	\$	943	\$	3,158
3.50	Prepare Antenna #22																	
3.50.1	Outfit & Verify Ant #22 at OSF																	
3.50.2	Move, Install & Verify Ant #22 on Site																	
3.51	Accept Antenna #23 at OSF		3		\$	29	\$	2,832			\$	854	\$	2,861	\$	943	\$	3,158
3.52	Prepare Antenna #23																	
3.52.1	Outfit & Verify Ant #23 at OSF																	
3.52.2	Move, Install & Verify Ant #23 on Site																	
3.53	Accept Antenna #24 at OSF		3		\$	29	\$	2,832			\$	854	\$	2,861	\$	943	\$	3,158
3.54	Prepare Antenna #24																	
3.54.1	Outfit & Verify Ant #24 at OSF																	
3.54.2	Move, Install & Verify Ant #24 on Site																	
3.55	Accept Antenna #25 at OSF		3		\$	29	\$	2,832			\$	854	\$	2,861	\$	943	\$	3,158
3.56	Prepare Antenna #25																	
3.56.1	Outfit & Verify Ant #25 at OSF																	
3.56.2	Move, Install & Verify Ant #25 on Site																	
3.57	Accept Antenna #26 at OSF		3		\$	29	\$	2,832			\$	854	\$	2,861	\$	943	\$	3,158
3.58	Prepare Antenna #26																	
3.58.1	Outfit & Verify Ant #26 at OSF																	
3.58.2	Move, Install & Verify Ant #26 on Site																	
3.59	Accept Antenna #27 at OSF		3		\$	29	\$	2,832			\$	854	\$	2,861	\$	943	\$	3,158
3.60	Prepare Antenna #27																	
3.60.1	Outfit & Verify Ant #27 at OSF																	
3.60.2	Move, Install & Verify Ant #27 on Site																	
3.61	Accept Antenna #28 at OSF																	
3.62	Prepare Antenna #28																	
3.62.1	Outfit & Verify Ant #28 at OSF																	
3.62.2	Move, Install & Verify Ant #28 on Site																	
3.63	Accept Antenna #29 at OSF																	
3.64	Prepare Antenna #29																	
3.64.1	Outfit & Verify Ant #29 at OSF																	
3.64.2	Move, Install & Verify Ant #29 on Site																	
3.65	Accept Antenna #30 at OSF																	
3.66	Prepare Antenna #30																	
3.66.1	Outfit & Verify Ant #30 at OSF																	
3.66.2	Move, Install & Verify Ant #30 on Site																	
3.67	Accept Antenna #31 at OSF																	
3.68	Prepare Antenna #31																	
3.68.1	Outfit & Verify Ant #31 at OSF																	
3.68.2	Move, Install and Verify Ant #31 on Site																	
3.69	Accept Antenna #32 at OSF																	
3.70	Prepare Antenna #32																	
3.70.1	Outfit & Verify Ant #32 at OSF																	
3.70.2	Move, Install & Verify Ant #32 on Site																	
3.71	Accept Antenna #33 at OSF																	
3.72	Prepare Antenna #33																	

4.1.8	Fab Rcvr Pckg Instrumentation & Electronics			3	12	\$ 88	\$ 100		\$ 21	\$ 37	\$ 167	\$ 41	\$ 184
4.1.9	Fabricate Receiver Inserts			18	30	\$ 322	\$ 100		\$ 47	\$ 64	\$ 375	\$ 71	\$ 414
4.1.10	Assemble Receiver Package												
4.1.10.1	Integrate Rcvr Instrumentation & subass'y			12	48	\$ 351	\$ 80		\$ 48	\$ 62	\$ 383	\$ 69	\$ 423
4.1.10.2	Deliver Receiver Package #1-6												
4.1.10.3	Deliver Receiver Package #7-16												
4.1.10.4	Deliver Receiver Package #17-26												
4.1.10.5	Deliver Receiver Package #27-36												
4.1.10.6	Deliver Receiver Package #37-40												
4.2	SIS Receiver Modules												
4.2.1	211-275 GHz Module												
4.2.1.1	SIS Mixer												
4.2.1.1.1	Design, Fab and Test Mixer Design												
4.2.1.1.2	Deliver Production Design												
4.2.1.1.3	Fabricate Production Mixers												
4.2.1.2	Design & Verify Optics												
4.2.1.3	Design Module												
4.2.1.4	Contract Fabrication												
4.2.1.4.1	Machine Mixer Blocks, Feed, WG, Lenses												
4.2.1.4.2	Assemble Modules												
4.2.1.5	Install SIS Mixer & Test Modules												
4.2.1.6	Deliver 211-275 GHz Receiver Modules												
4.2.1.6.1	Deliver Modules #1-7												
4.2.1.6.2	Deliver Modules #8-26												
4.2.1.6.3	Deliver Modules #27-40												
4.2.2	602-720 GHz Module												
4.2.2.1	SIS Mixer												
4.2.2.1.1	Design, Fabricate and Test Mixer Design												
4.2.2.1.2	Deliver Production Design												
4.2.2.1.3	Fabricate Production Mixers												
4.2.2.2	Design & Verify Optics												
4.2.2.3	Design Module												
4.2.2.4	Contract Fabrication												
4.2.2.4.1	Machine Mixer Blocks, Feed, WG, Lenses												
4.2.2.4.2	Assemble Modules												
4.2.2.5	Install SIS Mixer and Test Modules												
4.2.2.6	Deliver 602-720 GHz Receiver Modules												
4.2.2.6.1	Deliver Modules #1-7												
4.2.2.6.2	Deliver Modules #8-26												
4.2.2.6.3	Deliver Modules #27-40												
4.2.3	275-370 GHz Receiver Module												
4.2.3.1	SIS Mixer												
4.2.3.1.1	Design, Fabricate and Test Mixer Design												
4.2.3.1.2	Deliver Production Design												
4.2.3.1.3	Fabricate Production Mixers												
4.2.3.2	Design & Verify Optics												
4.2.3.3	Design Module												
4.2.3.4	Contract Fabrication												
4.2.3.4.1	Machine Mixer Blocks, Feed, WG, Lenses												
4.2.3.4.2	Assemble Modules												

4.2.3.5	Install SIS Mixer and Test Modules		18	36	\$ 351	\$ 40		\$ 43	\$ 52	\$ 348	\$ 57	\$ 384
4.2.3.6	Deliver 275-370 GHz Receiver Module											
4.2.3.6.1	Deliver Modules #1-5											
4.2.3.6.2	Deliver Modules #6-30											
4.2.3.6.3	Deliver Modules #30-40											
4.2.4	91-119 GHz Receiver Module											
4.2.4.1	SIS Mixer											
4.2.4.1.1	Design, Fabricate & Test Mixer Design											
4.2.4.1.2	Deliver Production Design											
4.2.4.1.3	Fabricate Production Mixers											
4.2.4.2	Design & Verify Optics											
4.2.4.3	Design Module											
4.2.4.4	Contract Fabrication											
4.2.4.4.1	Machine Mixer Blocks, Feed, WG, Lenses											
4.2.4.4.2	Assemble Modules											
4.2.4.5	Install SIS Mixer and Test Modules		18	36	\$ 351	\$ 40		\$ 43	\$ 52	\$ 348	\$ 57	\$ 384
4.2.4.6	Deliver 91-119 GHz Receiver Modules											
4.2.4.6.1	Deliver Modules #1-5											
4.2.4.6.2	Deliver Modules #6-30											
4.2.4.6.3	Deliver Modules # 31-40											
4.2.5	163-211 GHz Receiver Module											
4.2.5.1	SIS Mixer											
4.2.5.1.1	Design, Fabricate & Test Mixer Design											
4.2.5.1.2	Deliver Production Design											
4.2.5.1.3	Fabricate Production Mixers											
4.2.5.2	Design & Verify Optics											
4.2.5.3	Design Module											
4.2.5.4	Contract Fabrication			4	\$ 20	\$ 50		\$ 8	\$ 16	\$ 62	\$ 17	\$ 68
4.2.5.4.1	Machine Mixer Blocks, Feed, WG, Lenses											
4.2.5.4.2	Assemble Modules											
4.2.5.5	Install SIS Mixer and Test		18	36	\$ 351	\$ 30		\$ 42	\$ 49	\$ 339	\$ 54	\$ 374
4.2.5.6	Deliver 163-211 GHz Receiver Modules											
4.2.5.6.1	Deliver Modules #1-5											
4.2.5.6.2	Deliver Modules #6-30											
4.2.5.6.3	Deliver Modules #31-40											
4.2.6	385-500 GHz Receiver Module											
4.2.6.1	SIS Mixer											
4.2.6.1.1	Design, Fabricate & Test Mixer Design											
4.2.6.1.2	Deliver Production Design											
4.2.6.1.3	Fabricate Production Mixers											
4.2.6.2	Design and Verify Optics											
4.2.6.3	Design Module											
4.2.6.4	Contract Fabrication			4	\$ 20	\$ 50		\$ 70	\$ -	\$ -	\$ -	\$ -
4.2.6.4.1	Machine Mixer Blocks, Feed, WG, Lenses											
4.2.6.4.2	Assemble Modules											
4.2.6.5	Install SIS Mixer and Test		18	36	\$ 351	\$ 30		\$ 381	\$ -	\$ -	\$ -	\$ -
4.2.6.6	Deliver 385-500 GHz Receiver Modules											
4.2.6.6.1	Deliver Modules #1-5											
4.2.6.6.2	Deliver Modules #6-30											
4.2.6.6.3	Deliver Modules #31-40											

4.2.7	125-163 GHz Receiver Module			18	18	\$ 263	\$ 50		\$ 35	\$ 44	\$ 278	\$ 49	\$ 307
4.2.7.1	SIS Mixer								\$ -	\$ -	\$ -	\$ -	\$ -
4.2.7.1.1	Design, Fabricate & Test Mixer Design												
4.2.7.1.2	Deliver Production Design												
4.2.7.1.3	Fabricate Production Mixers												
4.2.7.2	Design & Verify Optics												
4.2.7.3	Design Module												
4.2.7.4	Contract Fabrication				4	\$ 20	\$ 100		\$ 13	\$ 29	\$ 106	\$ 32	\$ 117
4.2.7.4.1	Machine Mixer Blocks, Feed, WG, Lenses												
4.2.7.4.2	Assemble Modules												
4.2.7.5	Install SIS Mixer and Test												
4.2.7.6	Deliver 125-163 GHz Receiver Modules												
4.2.7.6.1	Deliver 125-163 GHz Modules #1-5												
4.2.7.6.2	Deliver 125-163 GHz Modules #6-30												
4.2.7.6.3	Deliver 125-163 GHz Modules #31-40												
4.3	HFET Receiver Modules			6	12	\$ 117	\$ 50		\$ 19	\$ 22	\$ 148	\$ 25	\$ 164
4.3.1	Contract for HFET Wafer												
4.3.2	Receive Diced HFET Wafer												
4.3.3	33-45 GHz Module												
4.3.3.1	Design Module												
4.3.3.2	Design & Verify Optics												
4.3.3.3	Contract Fabrication												
4.3.3.3.1	Machine Blocks, Feed, WG, Lenses												
4.3.3.3.2	Assemble Modules												
4.3.3.3.3	Flip-in Mirror												
4.3.4	Install HFET & Test Modules												
4.3.5	Deliver 33-45 GHz Receiver Modules												
4.3.5.1	Deliver Modules #1-20												
4.3.5.2	Deliver Modules #21-40												
4.3.6	67-95 GHz Module												
4.3.6.1	Design Amplifier												
4.3.6.2	Design Module												
4.3.6.3	Design & Verify Optics												
4.3.6.4	Contract Fabrication												
4.3.6.4.1	Machine Blocks, Feed, WG, Lenses												
4.3.6.4.2	Assemble Modules												
4.3.6.5	Install HFET & Test Modules												
4.3.6.6	Deliver 67-95 GHz Receiver Modules												
4.3.6.6.1	Deliver Modules 67-95GHz #1-20												
4.3.6.6.2	Deliver Modules 67-95GHz #21-40												
5	LO System												
5.1	LO Reference: Prototype Systems												
5.1.1	Deliver: Bench Prototype												
5.1.2	Testing and Design Refinement												
5.1.3	Procure/Fab Field Prototypes												
5.1.4	Deliver: LO Ref Field Prototypes												
5.1.5	Field Prototype testing and Design Refinement												
5.1.6	Preproduction Review												

5.1.7	Final Documentation and Design Modifications																		
5.1.8	Release for Manufacture																		
5.2	LO Reference: Production System		12	48	\$ 351						\$ 53	\$ 351	\$ 58	\$ 387					
5.1.1	Production test and lab equipment																		
5.1.2	H-maser Frequency Standard (& Rb)																		
5.1.3	8 GHz PL Oscillator & Distributor					\$ 1			\$ 0	\$ 0		\$ 1	\$ 0	\$ 1					
5.1.4	10 GHz PL Oscillator & Distributor					\$ 1			\$ 0	\$ 0		\$ 1	\$ 0	\$ 1					
5.1.5	12 GHz PL Oscillator & Distributor					\$ 1			\$ 0	\$ 0		\$ 1	\$ 0	\$ 1					
5.1.6	14 GHz PL Oscillator & Distributor					\$ 1			\$ 0	\$ 0		\$ 1	\$ 0	\$ 1					
5.1.7	3.2-5.2 GHz Synthesizer					\$ 8			\$ 1	\$ 7		\$ 7	\$ 1	\$ 8					
5.1.8	3.2 -5.2 GHz PLO and Fringe Generator					\$ 160			\$ 18	\$ 21		\$ 142	\$ 24	\$ 157					
5.1.9	Sampler Clock 4 GHz PL Osc & Distributor					\$ 1			\$ 0	\$ 0		\$ 1	\$ 0	\$ 1					
5.1.10	LO Ref Generator					\$ 2			\$ 0	\$ 0		\$ 2	\$ 0	\$ 2					
5.1.11	LO Ref Distributor - Control Bldg					\$ 1			\$ 0	\$ 0		\$ 1	\$ 0	\$ 1					
5.1.12	Microwave Round-trip Phase Measurement					\$ 60			\$ 7	\$ 8		\$ 53	\$ 9	\$ 59					
5.1.13	10-15 GHz Frequency Synthesizer					\$ 100			\$ 11	\$ 13		\$ 89	\$ 15	\$ 98					
5.1.14	First LO Fringe Generator					\$ 20			\$ 2	\$ 3		\$ 18	\$ 3	\$ 20					
5.1.15	16 GHz PL Oscillator					\$ 40			\$ 4	\$ 5		\$ 36	\$ 6	\$ 39					
5.1.16	26 GHz PL Oscillator					\$ 40			\$ 4	\$ 5		\$ 36	\$ 6	\$ 39					
5.1.17	LO Ref Distributor - Antenna					\$ 20			\$ 2	\$ 3		\$ 18	\$ 3	\$ 20					
5.1.18	VXCO Clean-up Loop					\$ 20			\$ 2	\$ 3		\$ 18	\$ 3	\$ 20					
5.1.19	Power supply module					\$ 60			\$ 7	\$ 8		\$ 53	\$ 9	\$ 59					
5.1.20	Bins / Racks (assemble and test)					\$ 16			\$ 2	\$ 2		\$ 14	\$ 2	\$ 16					
5.3	Millimeter LO Drivers																		
5.3.1	Design and System Integration		3		\$ 29	\$ 50					\$ 19	\$ 79	\$ 21	\$ 87					
5.3.2	72-95 GHz Source																		
5.3.2.1	Contract Procurement and Fabrication																		
5.3.2.1.1	YIG-tuned Oscillator																		
5.3.2.1.2	18.00 - 23.75 GHz 10 db Amplifier																		
5.3.2.1.3	18.00 - 23.75 GHz x2 Multiplier																		
5.3.2.1.4	36.0 - 47.5 GHz 10 db Amplifier																		
5.3.2.1.5	36.0 - 47.5 GHz x2 Multiplier																		
5.3.2.1.6	Mount and Tuning circuitry																		
5.3.2.2	Assembly and Test																		
5.3.2.3	Deliver 72 - 95 GHz LO Sources																		
5.3.2.3.1	Deliver Modules #1-6																		
5.3.2.3.2	Deliver Modules #7-24																		
5.3.2.3.3	Deliver Modules #25-40																		
5.3.3	100-120 GHz Source																		
5.3.3.1	Contract Procurement and Fabrication																		
5.3.3.1.1	YIG-tuned Oscillator																		
5.3.3.1.2	25.00 - 30.00 GHz 10 db Amplifier																		
5.3.3.1.3	15.00 - 30.00 GHz x2 Multiplier																		
5.3.3.1.4	50.0 - 60.0 GHz 10 db Amplifier																		
5.3.3.1.5	50-60 GHz x2 Multiplier																		
5.3.3.1.6	Mount and Tuning circuitry																		
5.3.3.2	Assembly and Test																		
5.3.3.3	Deliver 100 - 120 GHz LO Sources																		
5.3.3.3.1	Deliver Modules #1-3																		
5.3.3.3.2	Deliver Modules #4-21																		
5.3.3.3.3	Deliver Modules #22-40																		

5.3.4	87 - 108 GHz Source				3	\$	15			\$	2	\$	15	\$	2	\$	16
5.3.4.1	Contract Procurement and Fabrication																
5.3.4.1.1	YIG-tuned Oscillator																
5.3.4.1.2	21.75-27.00 GHz 10 db Amplifier																
5.3.4.1.3	21.75-27.00 GHz x2 Multiplier																
5.3.4.1.4	43.5-54.0 GHz 10 db Amplifier																
5.3.4.1.5	43.5-54.0 GHz x2 Multiplier																
5.3.4.1.6	Mount and Tuning Circuitry																
5.3.4.2	Assembly and Test																
5.3.4.3	Deliver 87 - 108 GHz LO Sources																
5.3.4.3.1	Deliver Modules #1-6																
5.3.4.3.2	Deliver Modules #7-20																
5.3.4.3.3	Deliver Modules #21-35																
5.3.4.3.4	Deliver Modules #36-40																
5.3.5	65 - 85 GHz Source				3	\$	15			\$	2	\$	15	\$	2	\$	16
5.3.5.1	Contract Procurement and Fabrication																
5.3.5.1.1	YIG-tuned Oscillator																
5.3.5.1.2	16.25-21.25 GHz 10 db Amplifier																
5.3.5.1.3	16.25-21.25 GHz x2 Multiplier																
5.3.5.1.4	32.5-42.5 GHz 10 db Amplifier																
5.3.5.1.5	32.5-42.5 GHz x2 Multiplier																
5.3.5.1.6	Mount and Tuning Circuitry																
5.3.5.2	Assembly and Test																
5.3.5.3	Deliver 65 - 85 GHz LO Sources																
5.3.5.3.1	Deliver Modules #1-6																
5.3.5.3.2	Deliver Modules #7-20																
5.3.5.3.3	Deliver Modules #21-35																
5.3.5.3.4	Deliver Modules #36-40																
5.4	Millimeter LO Multiplier Chains			2		\$	20			\$	3	\$	20	\$	3	\$	22
5.4.1	Design and System Integration																
5.4.2	211 - 275 GHz Receiver LO																
5.4.2.1	Contract Fabrication																
5.4.2.1.1	X3 Diode for 72-95 GHz Source																
5.4.2.1.2	Machine Mount																
5.4.2.1.3	Bias and Control circuits																
5.4.2.2	Assemble Multiplier and Test																
5.4.2.3	Integrate Source and Multiplier; test																
5.4.2.4	Deliver 211-275 GHz Rcvr LO Modules																
5.4.2.4.1	Deliver Modules #1-3																
5.4.2.4.2	Deliver Modules #4-21																
5.4.2.4.3	Deliver Modules #22-40																
5.4.3	602 - 720 GHz Receiver LO																
5.4.3.1	Contract Fabrication																
5.4.3.1.1	X2 Diode for 100-120 GHz Source																
5.4.3.1.2	X3 Diode for 200-240 GHz Input																
5.4.3.1.3	Machine Mount																
5.4.3.1.4	Bias and Control circuits																
5.4.3.2	Assemble Multipliers and Test																
5.4.3.3	Integrate Source and Multipliers; test																

5.4.3.4	Deliver 602-720 GHz Rcvr LO Modules																			
5.4.3.4.1	Deliver Modules #1-6																			
5.4.3.4.2	Deliver Modules #7-18																			
5.4.3.4.3	Deliver Modules #19-34																			
5.4.3.4.4	Deliver Modules #35-40																			
5.4.4	275 - 370 GHz Receiver LO																			
5.4.4.1	Contract Fabrication																			
5.4.4.1.1	X2 Diode for 72-95 GHz Source																			
5.4.4.1.2	X2 Diode for 144-190 GHz Input																			
5.4.4.1.3	Machine Mount																			
5.4.4.1.4	Bias and Control Circuits																			
5.4.4.2	Assemble Multipliers and Test																			
5.4.4.3	Integrate Source and Multipliers; test																			
5.4.4.4	Deliver 275-370 GHz Rcvr LO Modules																			
5.4.4.4.1	Deliver Modules #1-6																			
5.4.4.4.2	Deliver Modules #7-27																			
5.4.4.4.3	Deliver Modules #28-40																			
5.4.5	163 - 211 GHz Receiver LO		3		18	\$	117	\$	50		\$	19	\$	27	\$	148	\$	30	\$	164
5.4.5.1	Contract Fabrication																			
5.4.5.1.1	X2 Diode for 87-108 GHz Source																			
5.4.5.1.2	Machine Mount																			
5.4.5.1.3	Bias and Control Circuits																			
5.4.5.2	Assemble Multiplier and Test																			
5.4.5.3	Integrate Source and Multiplier; test																			
5.4.5.4	Deliver 163 - 211 GHz Rcvr LO Modules																			
5.4.5.4.1	Deliver Modules #1-6																			
5.4.5.4.2	Deliver Modules #7-24																			
5.4.5.4.3	Deliver Modules #25-40																			
5.4.6	385 - 500 GHz Receiver LO		3		18	\$	117	\$	50		\$	19	\$	27	\$	148	\$	30	\$	164
5.4.6.1	Contract Fabrication																			
5.4.6.1.1	X3 Diode for 65-85 GHz Source																			
5.4.6.1.2	X2 Diode for 130-170 GHz Input																			
5.4.6.1.3	Machine Mount																			
5.4.6.1.4	Bias and Control Circuits																			
5.4.6.2	Assemble Multiplier and test																			
5.4.6.3	Integrate source and Multiplier; test																			
5.4.6.4	Deliver 385-500 GHz Rcvr LO Modules																			
5.4.6.4.1	Deliver Modules #1-6																			
5.4.6.4.2	Deliver Modules #7-24																			
5.4.6.4.3	Deliver Modules #25-40																			
5.4.7	125 - 163 GHz Receiver LO		3		18	\$	117	\$	50		\$	19	\$	27	\$	148	\$	30	\$	164
5.4.7.1	Contract Fabrication																			
5.4.7.1.1	X2 Diode for 65 - 85 GHz Source																			
5.4.7.1.2	Machine Mount																			
5.4.7.1.3	Bias and Control Circuits																			
5.4.7.2	Assemble Multiplier and test																			
5.4.7.3	Integrate Source and Multiplier; test																			
5.4.7.4	Deliver 125-163 GHz Rcvr LO Modules																			
5.4.7.4.1	Deliver Modules #1-6																			

5.4.7.4.2	Deliver Modules #7-18																	
5.4.7.4.3	Deliver Modules #19-34																	
5.4.7.4.4	Deliver Modules #35-40																	
5.4.8	33-45 GHz Receiver LO																	
5.4.8.1	Design & Fab Selection & Coupling from Sources																	
6	IF System	12	36	\$	293				\$	44	\$	293	\$	48	\$	323		
6.1	IF System: Prototype Systems																	
6.1.1	Deliver (Bench) Prototype IF System																	
6.1.2	Testing and Design Refinement																	
6.1.3	Procure/Fab Field Prototypes																	
6.1.4	Deliver IF Field Prototypes to Test Interferometer																	
6.1.5	Field Prototype testing and Design Refinement																	
6.1.6	Preproduction Review																	
6.1.7	Final Documentation and Design Modifications																	
6.1.8	Release for Manufacture																	
6.2	Production test and lab equipment																	
6.3	IF Multiplexer					\$	160		\$	18	\$	21	\$	142	\$	24	\$	157
6.4	IF Demultiplexer					\$	80		\$	9	\$	11	\$	71	\$	12	\$	78
6.5	IF Matrix Switch					\$	64		\$	7	\$	9	\$	57	\$	9	\$	63
6.6	Baseband Converter					\$	160		\$	18	\$	21	\$	142	\$	24	\$	157
6.7	Power supply module					\$	40		\$	4	\$	5	\$	36	\$	6	\$	39
6.8	Bins / Racks (assemble and test)					\$	16		\$	2	\$	2	\$	14	\$	2	\$	16
7	Optical Fiber System	12	36	\$	293				\$	44	\$	293	\$	48	\$	323		
7.1	Optical Fiber System: Prototype Systems																	
7.1.1	Deliver (Bench) Prototype FO System																	
7.1.2	Testing and Design Refinement																	
7.1.3	Procure/Fab Field Prototypes																	
7.1.4	Deliver FO Field Prototypes to Test Interferometer																	
7.1.5	Field Prototype testing and Design Refinement																	
7.1.6	Preproduction Review																	
7.1.7	Final Documentation and Design Modifications																	
7.1.8	Release for Manufacture																	
7.1	Production test and lab equipment																	
7.2	IF TX / RX					\$	240		\$	27	\$	32	\$	213	\$	35	\$	235
7.3	LO Reference TX / RX					\$	40		\$	4	\$	5	\$	36	\$	6	\$	39
7.4	Microwave Round-trip Phase TX / RX					\$	40		\$	4	\$	5	\$	36	\$	6	\$	39
7.5	Monitor / Control TX / RX					\$	20		\$	2	\$	3	\$	18	\$	3	\$	20
7.6	Power supply module					\$	40		\$	4	\$	5	\$	36	\$	6	\$	39
7.7	Bins / Racks (assemble and test)					\$	16		\$	2	\$	2	\$	14	\$	2	\$	16
8	Correlator	36	36	\$	527	\$	1,000		\$	170	\$	328	\$	1,357	\$	362	\$	1,498
8.1	Digital Sampler, 4 GHz																	
8.1.1	Refine Design																	
8.1.2	Release Digital Sampler for Manufacture																	
8.1.3	Contract Materials																	
8.1.4	Assembly																	
8.1.5	Validation and Delivery																	

8.8.4.4	Deliver 1/4 Correlator to MMA site													
8.9	Continued Support													
9	Computing					\$ 400			\$ 120	\$ 400	\$ 132	\$ 442		
9.1	Control Software													
9.1.1	Test Interferometer Control & Analysis													
9.1.2	MMA correlator software													
9.1.3	Multi-antenna & sub-array control													
9.1.4	Operators & Observers interfaces													
9.1.5	Deliver Control Software													
9.1.6	Maintenance	40				\$ 347	\$ 347	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
9.2	Scheduling													
9.2.1	Static scheduling system													
9.2.2	Dynamic scheduling simulations													
9.2.3	Dynamic scheduling prototype													
9.2.4	Dynamic scheduling implementation	26				\$ 225		\$ 34	\$ 225	\$ 37	\$ 249			
9.2.5	Initial Operations with Dynamic Scheduling													
9.3	Proposal Preparation Software													
9.3.1	Prototype													
9.3.2	Production version	10				\$ 87		\$ 13	\$ 87	\$ 14	\$ 96			
9.4	Image Pipeline													
9.4.1	Automated calibration & imaging heuristics													
9.4.2	Prototype image pipeline													
9.4.3	Parallelization studies and implementation	12				\$ 104		\$ 16	\$ 104	\$ 17	\$ 115			
9.4.4	Initial Image Pipeline Operations	20				\$ 173		\$ 26	\$ 173	\$ 29	\$ 191			
9.4.5	Production image pipeline													
9.5	Archiving													
9.5.1	Prototype distributed archive													
9.5.2	Evaluate storage hardware													
9.5.3	Production archive	20				\$ 173		\$ 26	\$ 173	\$ 29	\$ 191			
9.5.4	Data Archive operational													
9.6	Post-processing													
9.6.1	Define MMA Data formats													
9.6.2	MMA filler & format conversions													
9.6.3	MMA-specific calibrations													
9.6.4	MMA Post-processing begins													
9.6.5	Maintenance	26				\$ 225	\$ 225	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
10	System Integration													
10.4	Test Interferometer Site Preparation													
10.4.1	Complete Office and Lab Space Preparation													
10.4.2	Cabling													
10.4.3	Test Interferometer Site Complete													
10.10.4	Prototype Antenna Outfitting													
10.10.4.1	Cabling													
10.10.4.2	Instrumentation													
10.10.4.3	Eval. Rcvr. #1 / Ant. #1 Integration													
10.10.4.4	Antenna #1 Outfitting Complete													
10.10.5	Integration Holography System/Antenna													
10.10.6	Integration Metrology/Antenna													
10.10.7	Antenna #1 Integration & Testing													

11.3.5	Integration on Production Antennas												
11.4	Imaging Studies & Project Support	72				\$ 585	\$ 585	\$ -	\$ -	\$ -	\$ -		
11.5	Imaging Algorithm Development	8	4			\$ 100		\$ 15	\$ 100	\$ 17	\$ 110		
TOTALS						\$ 10,180	\$ 41,193	\$ 2,074	\$ 1,274	\$ 12,571	\$ 48,026	\$ 13,876	\$ 53,011

Millimeter Array Construction 2006

WBS	Name	Scientists Work-Months	Programmers Work-Months	Engineers Work-Months	Technicians Work-Months	Personnel Cost	Materials and Supplies	Transfer to Operations	Adjustment to Scope	Contingency	Sum Cost	Inflated Contingency	Inflated Sum
1	Administration												
1.1	Project Management	72			48	\$ 819		\$ 215		\$ 91	\$ 605	\$ 103	\$ 684
1.1.1	Management, Planning, and Oversight						\$ 700			\$ 105	\$ 700	\$ 119	\$ 792
1.1.2	Business Operations						\$ 100			\$ 15	\$ 100	\$ 17	\$ 113
1.1.3	Chilean Operations						\$ 50			\$ 8	\$ 50	\$ 8	\$ 57
1.1.4	Safety and Health												
1.1.5	Personnel												
1.1.6	Project Science Office												
1.1.7	AUI Management						\$ 350			\$ -	\$ 350	\$ -	\$ 396
1.2	Engineering			24	12	\$ 293	\$ 20			\$ 47	\$ 313	\$ 53	\$ 354
1.2.1	System Engineering--Phase II												
1.2.2	Documentation System												
1.2.3	Production Engineering												
1.3	US Facilities												
1.3.1	CDL Permanent Facilities												
1.3.2	Manufacturing Facilities						\$ 100			\$ 15	\$ 100	\$ 17	\$ 113
1.3.3	Common Infrastructure						\$ 200			\$ 30	\$ 200	\$ 34	\$ 226
2	Site Development			12		\$ 117	\$ 50			\$ 25	\$ 167	\$ 28	\$ 189
2.1	Review Legalities Regarding Array and OSF Sites												
2.2	Maintain Mining claims						\$ 25			\$ -	\$ 25	\$ -	\$ 28
2.3	Contract A&E Studies												
2.4	Hire Construction Manager for Chile												
2.5	Array Site												
2.5.1	Prepare Site Development Bid Packages												
2.5.1.1	Prepare Package for Array Site												
2.5.1.2	Review Bid Packages												
2.5.1.3	Bid Civil Works Construction												
2.5.2	Evaluate Array Site Bid Response												
2.5.2.1	Review Bids												
2.5.2.2	Recommend Contractors												
2.5.2.3	Award Array Site Contracts												
2.5.3	Contract Array Site Civil Works												
2.5.3.1	Array Site												
2.5.3.2	Inspect Completed Site Constr												
2.5.3.3	Accept Site Facility												
2.6	Operations Support Facility												
2.6.1	Prepare OSF Bid Packages												
2.6.1.1	Prepare Package for OSF												
2.6.1.2	Review Bid Packages												
2.6.1.3	Bid Civil Works Construction												
2.6.2	Evaluate OSF Bid Response												
2.6.2.1	Review Bids												
2.6.2.2	Recommend Contractors												
2.6.2.3	Award Contracts												

2.6.3	Contract OSF Civil Works																				
2.6.3.1	Operations Support Facility																				
2.6.3.2	Inspect Completed OSF Constr																				
2.6.3.3	Accept OSF Facility																				
2.7	OSF/Array Link																				
2.7.1	Prepare OSF/Array Link Bid Package																				
2.7.1.1	Prepare Package for OSF/Array F/O Link																				
2.7.1.2	Review Bid Package																				
2.7.1.3	Bid OSF/Array Link Construction																				
2.7.2	Evaluate Bid Response																				
2.7.2.1	Review Bids																				
2.7.2.2	Recommend Contractors																				
2.7.2.3	Award Contracts																				
2.7.3	Contract Civil Works																				
2.7.3.1	OSF/Array Link																				
2.7.3.2	Inspect Completed OSF/Array Link Constr																				
2.7.3.3	Accept OSF/Array Link																				
2.8	Prepare for Instrument Assembly																				
2.8.1	Equip Array Site																				
2.8.2	Equip Operations Support Facility																				
3	Antenna																				
3.1	Antenna Engineering Support																				
3.3.40	Acceptance Tests Antenna #1																				
3.3.45	Delivery of Antenna #1																				
3.8.10	Sign Transporter Contract																				
3.8.15	Transporter Acceptance tests																				
3.8.20	Deliver/Accept Transporter #1																				
3.7	Procurement of Antenna #2																				
3.7.1	Antenna #2 Contract Supervision																				
3.7.2	Antenna #2 Acceptance tests																				
3.8	Negotiate Production Antenna Contract																				
3.9	Sign Contract for Production Antennas																				
3.10	Antenna Contract Supervision																				
3.11	Accept Antenna #3 at OSF																				
3.12	Prepare Antenna #3																				
3.12.1	Outfit & Verify Ant #3 at OSF																				
3.12.2	Move, Install & Verify Ant #3 on Site																				
3.13	Accept Antenna #4 at OSF																				
3.14	Prepare Antenna #4																				
3.14.1	Outfit & Verify Ant #4 at OSF																				
3.14.2	Move, Install & Verify Ant #4 on Site																				
3.15	Accept Antenna#5 at OSF																				
3.16	Prepare Antenna #5																				
3.16.1	Outfit & Verify Ant #5 at OSF																				
3.16.2	Move, Install & Verify Ant #5 on Site																				
3.17	Accept Antenna#6 at OSF																				
3.18	Prepare Antenna #6																				
3.18.1	Outfit & Verify Ant #6 at OSF																				
3.18.2	Move, Install & Verify Ant #6 on Site																				

3.46	Prepare Antenna #20																	
3.46.1	Outfit & Verify Ant #20 at OSF	2	4	\$	39					\$	6	\$	39	\$	7	\$	44	
3.46.2	Move, Install & Verify Ant #20 on Site	1	1	\$	15					\$	2	\$	15	\$	2	\$	17	
3.47	Accept Antenna #21 at OSF	1.5		\$	15					\$	2	\$	15	\$	2	\$	17	
3.48	Prepare Antenna #21																	
3.48.1	Outfit & Verify Ant #21 at OSF	2	4	\$	39					\$	6	\$	39	\$	7	\$	44	
3.48.2	Move, Install & Verify Ant #21 on Site	1	1	\$	15					\$	2	\$	15	\$	2	\$	17	
3.49	Accept Antenna #22 at OSF	1.5		\$	15					\$	2	\$	15	\$	2	\$	17	
3.50	Prepare Antenna #22																	
3.50.1	Outfit & Verify Ant #22 at OSF	2	4	\$	39					\$	6	\$	39	\$	7	\$	44	
3.50.2	Move, Install & Verify Ant #22 on Site	1	1	\$	15					\$	2	\$	15	\$	2	\$	17	
3.51	Accept Antenna #23 at OSF	1.5		\$	15					\$	2	\$	15	\$	2	\$	17	
3.52	Prepare Antenna #23																	
3.52.1	Outfit & Verify Ant #23 at OSF	2	4	\$	39					\$	6	\$	39	\$	7	\$	44	
3.52.2	Move, Install & Verify Ant #23 on Site	1	1	\$	15					\$	2	\$	15	\$	2	\$	17	
3.53	Accept Antenna #24 at OSF	1.5		\$	15					\$	2	\$	15	\$	2	\$	17	
3.54	Prepare Antenna #24																	
3.54.1	Outfit & Verify Ant #24 at OSF	2	4	\$	39					\$	6	\$	39	\$	7	\$	44	
3.54.2	Move, Install & Verify Ant #24 on Site	1	1	\$	15					\$	2	\$	15	\$	2	\$	17	
3.55	Accept Antenna #25 at OSF	1.5		\$	15					\$	2	\$	15	\$	2	\$	17	
3.56	Prepare Antenna #25																	
3.56.1	Outfit & Verify Ant #25 at OSF	2	4	\$	39					\$	6	\$	39	\$	7	\$	44	
3.56.2	Move, Install & Verify Ant #25 on Site	1	1	\$	15					\$	2	\$	15	\$	2	\$	17	
3.57	Accept Antenna #26 at OSF	1.5		\$	15					\$	2	\$	15	\$	2	\$	17	
3.58	Prepare Antenna #26																	
3.58.1	Outfit & Verify Ant #26 at OSF	2	4	\$	39					\$	6	\$	39	\$	7	\$	44	
3.58.2	Move, Install & Verify Ant #26 on Site	1	1	\$	15					\$	2	\$	15	\$	2	\$	17	
3.59	Accept Antenna #27 at OSF	1.5		\$	15					\$	2	\$	15	\$	2	\$	17	
3.60	Prepare Antenna #27																	
3.60.1	Outfit & Verify Ant #27 at OSF	2	4	\$	39					\$	6	\$	39	\$	7	\$	44	
3.60.2	Move, Install & Verify Ant #27 on Site	1	1	\$	15					\$	2	\$	15	\$	2	\$	17	
3.61	Accept Antenna #28 at OSF	3		\$	29	\$	2,832			\$	854	\$	2,861	\$	966	\$	3,237	
3.62	Prepare Antenna #28																	
3.62.1	Outfit & Verify Ant #28 at OSF																	
3.62.2	Move, Install & Verify Ant #28 on Site																	
3.63	Accept Antenna #29 at OSF	3		\$	29	\$	2,832			\$	854	\$	2,861	\$	966	\$	3,237	
3.64	Prepare Antenna #29																	
3.64.1	Outfit & Verify Ant #29 at OSF																	
3.64.2	Move, Install & Verify Ant #29 on Site																	
3.65	Accept Antenna #30 at OSF	3		\$	29	\$	2,832			\$	854	\$	2,861	\$	966	\$	3,237	
3.66	Prepare Antenna #30																	
3.66.1	Outfit & Verify Ant #30 at OSF																	
3.66.2	Move, Install & Verify Ant #30 on Site																	
3.67	Accept Antenna #31 at OSF	3		\$	29	\$	2,832			\$	854	\$	2,861	\$	966	\$	3,237	
3.68	Prepare Antenna #31																	
3.68.1	Outfit & Verify Ant #31 at OSF																	
3.68.2	Move, Install and Verify Ant #31 on Site																	
3.69	Accept Antenna #32 at OSF	3		\$	29	\$	2,832			\$	854	\$	2,861	\$	966	\$	3,237	
3.70	Prepare Antenna #32																	
3.70.1	Outfit & Verify Ant #32 at OSF																	
3.70.2	Move, Install & Verify Ant #32 on Site																	
3.71	Accept Antenna #33 at OSF	3		\$	29	\$	2,832		\$	2,861	\$	-	\$	-	\$	-	\$	-
3.72	Prepare Antenna #33																	

3.72.1	Outfit & Verify Ant #33 at OSF																				
3.72.2	Move, Install and Verify Ant #33 on Site																				
3.73	Accept Antenna #34 at OSF		3		\$	29	\$	2,832		\$	2,861	\$	-	\$	-	\$	-	\$	-		
3.74	Prepare Antenna #34																				
3.74.1	Outfit & Verify Ant #34 at OSF																				
3.74.2	Move, Install and Verify Ant #34 on Site																				
3.75	Accept Antenna #35 at OSF		3		\$	29	\$	2,832		\$	2,861	\$	-	\$	-	\$	-	\$	-		
3.76	Prepare Antenna #35																				
3.76.1	Outfit & Verify Ant #35 at OSF																				
3.76.2	Move, Install & Verify Ant #35 on Site																				
3.77	Accept Antenna #36 at OSF		3		\$	29	\$	2,832		\$	2,861	\$	-	\$	-	\$	-	\$	-		
3.78	Prepare Antenna #36																				
3.78.1	Outfit & Verify Ant #36 at OSF																				
3.78.2	Move, Install & Verify Ant #36 on Site																				
3.79	Prepare Antenna #1																				
3.79.1	Antenna #1 Reassembled at OSF																				
3.79.2	Outfit & Verify Ant #1 at OSF																				
3.79.3	Move, Install & Verify Ant #1 on Site																				
3.80	Prepare Antenna #2																				
3.80.1	Antenna #2 Reassembled at OSF																				
3.80.2	Outfit & Verify Ant #2 at OSF																				
3.80.3	Move, Install & Verify Ant #2 on Site																				
3.81	Antenna Transporter																				
3.81.1	Contract for Transporter #1, move to Site																				
3.81.2	Contract for Transporters #2, #3																				
3.81.3	Accept Transporters #2, #3 at OSF																				
4	Receivers																				
4.1	Receiver Package																				
4.1.1	Prototype Production Receiver Cryogenics																				
4.1.1.1	CDR: Cryogenics Development																				
4.1.1.2	Construct & test prototype cryogenics																				
4.1.1.3	Deliver Prototype Cryogenics Subsystem																				
4.1.2	Prototype Production Receiver Package																				
4.1.2.1	Prototype Receiver Package Integration																				
4.1.2.2	Prot. Rcvr. Pckg Lab Test & Evaluation																				
4.1.2.3	Complete Prototype MMA Receiver Package																				
4.1.3	MMA Rcvr Pckg Design Refinement																				
4.1.4	Documentation																				
4.1.5	Release MMA Receiver Pckg for manufacture																				
4.1.6	Contract for Receiver Pckg Subassemblies																				
4.1.6.1	Machine Dewars					30	\$	146	\$	50		\$	22	\$	30	\$	174	\$	34	\$	197
4.1.6.2	Fabricate Cryogenics subsystems					24	\$	176	\$	240		\$	46	\$	84	\$	369	\$	96	\$	418
4.1.6.3	Fabricate windows, IR filters, etc					6	\$	30	\$	205		\$	34	\$	51	\$	271	\$	57	\$	306
4.1.7	Accept Receiver Pckg Subassemblies																				
4.1.7.1	Subassemblies #1-6																				
4.1.7.2	Subassemblies #7-16																				
4.1.7.3	Subassemblies #17-26																				
4.1.7.4	Subassemblies #27-36																				
4.1.7.5	Subassemblies #37-40																				

4.1.8	Fab Rcvr Pckg Instrumentation & Electronics		3	12	\$ 88	\$ 75		\$ 18	\$ 30	\$ 145	\$ 34	\$ 164
4.1.9	Fabricate Receiver Inserts		18	30	\$ 322	\$ 100		\$ 47	\$ 64	\$ 375	\$ 73	\$ 424
4.1.10	Assemble Receiver Package				\$ -							
4.1.10.1	Integrate Rcvr Instrumentation & subass'y		12	48	\$ 351	\$ 80		\$ 48	\$ 62	\$ 383	\$ 70	\$ 433
4.1.10.2	Deliver Receiver Package #1-6											
4.1.10.3	Deliver Receiver Package #7-16											
4.1.10.4	Deliver Receiver Package #17-26											
4.1.10.5	Deliver Receiver Package #27-36											
4.1.10.6	Deliver Receiver Package #37-40											
4.2	SIS Receiver Modules											
4.2.1	211-275 GHz Module											
4.2.1.1	SIS Mixer											
4.2.1.1.1	Design, Fab and Test Mixer Design											
4.2.1.1.2	Deliver Production Design											
4.2.1.1.3	Fabricate Production Mixers											
4.2.1.2	Design & Verify Optics											
4.2.1.3	Design Module											
4.2.1.4	Contract Fabrication											
4.2.1.4.1	Machine Mixer Blocks, Feed, WG, Lenses											
4.2.1.4.2	Assemble Modules											
4.2.1.5	Install SIS Mixer & Test Modules											
4.2.1.6	Deliver 211-275 GHz Receiver Modules											
4.2.1.6.1	Deliver Modules #1-7											
4.2.1.6.2	Deliver Modules #8-26											
4.2.1.6.3	Deliver Modules #27-40											
4.2.2	602-720 GHz Module											
4.2.2.1	SIS Mixer											
4.2.2.1.1	Design, Fabricate and Test Mixer Design											
4.2.2.1.2	Deliver Production Design											
4.2.2.1.3	Fabricate Production Mixers											
4.2.2.2	Design & Verify Optics											
4.2.2.3	Design Module											
4.2.2.4	Contract Fabrication											
4.2.2.4.1	Machine Mixer Blocks, Feed, WG, Lenses											
4.2.2.4.2	Assemble Modules											
4.2.2.5	Install SIS Mixer and Test Modules											
4.2.2.6	Deliver 602-720 GHz Receiver Modules											
4.2.2.6.1	Deliver Modules #1-7											
4.2.2.6.2	Deliver Modules #8-26											
4.2.2.6.3	Deliver Modules #27-40											
4.2.3	275-370 GHz Receiver Module											
4.2.3.1	SIS Mixer											
4.2.3.1.1	Design, Fabricate and Test Mixer Design											
4.2.3.1.2	Deliver Production Design											
4.2.3.1.3	Fabricate Production Mixers											
4.2.3.2	Design & Verify Optics											
4.2.3.3	Design Module											
4.2.3.4	Contract Fabrication											
4.2.3.4.1	Machine Mixer Blocks, Feed, WG, Lenses											
4.2.3.4.2	Assemble Modules											

4.2.7	125-163 GHz Receiver Module			24	24	\$ 351	\$ 50		\$ 45	\$ 54	\$ 356	\$ 61	\$ 403
4.2.7.1	SIS Mixer								\$ -	\$ -	\$ -	\$ -	\$ -
4.2.7.1.1	Design, Fabricate & Test Mixer Design												
4.2.7.1.2	Deliver Production Design												
4.2.7.1.3	Fabricate Production Mixers												
4.2.7.2	Design & Verify Optics												
4.2.7.3	Design Module												
4.2.7.4	Contract Fabrication				4	\$ 20	\$ 100		\$ 13	\$ 29	\$ 106	\$ 33	\$ 120
4.2.7.4.1	Machine Mixer Blocks, Feed, WG, Lenses												
4.2.7.4.2	Assemble Modules												
4.2.7.5	Install SIS Mixer and Test			24	48	\$ 468	\$ 50		\$ 58	\$ 68	\$ 460	\$ 77	\$ 521
4.2.7.6	Deliver 125-163 GHz Receiver Modules												
4.2.7.6.1	Deliver 125-163 GHz Modules #1-5												
4.2.7.6.2	Deliver 125-163 GHz Modules #6-30												
4.2.7.6.3	Deliver 125-163 GHz Modules #31-40												
4.3	HFET Receiver Modules												
4.3.1	Contract for HFET Wafer												
4.3.2	Receive Diced HFET Wafer												
4.3.3	33-45 GHz Module												
4.3.3.1	Design Module												
4.3.3.2	Design & Verify Optics												
4.3.3.3	Contract Fabrication												
4.3.3.3.1	Machine Blocks, Feed, WG, Lenses												
4.3.3.3.2	Assemble Modules												
4.3.3.3.3	Flip-in Mirror												
4.3.4	Install HFET & Test Modules												
4.3.5	Deliver 33-45 GHz Receiver Modules												
4.3.5.1	Deliver Modules #1-20												
4.3.5.2	Deliver Modules #21-40												
4.3.6	67-95 GHz Module												
4.3.6.1	Design Amplifier												
4.3.6.2	Design Module												
4.3.6.3	Design & Verify Optics												
4.3.6.4	Contract Fabrication												
4.3.6.4.1	Machine Blocks, Feed, WG, Lenses												
4.3.6.4.2	Assemble Modules												
4.3.6.5	Install HFET & Test Modules												
4.3.6.6	Deliver 67-95 GHz Receiver Modules												
4.3.6.6.1	Deliver Modules 67-95GHz #1-20												
4.3.6.6.2	Deliver Modules 67-95GHz #21-40												
5	LO System												
5.1	LO Reference: Prototype Systems												
5.1.1	Deliver: Bench Prototype												
5.1.2	Testing and Design Refinement												
5.1.3	Procure/Fab Field Prototypes												
5.1.4	Deliver: LO Ref Field Prototypes												
5.1.5	Field Prototype testing and Design Refinement												
5.1.6	Preproduction Review												

5.1.7	Final Documentation and Design Modifications																	
5.1.8	Release for Manufacture																	
5.2	LO Reference: Production System		12	48	\$	351			\$	53	\$	351	\$	60	\$	397		
5.1.1	Production test and lab equipment																	
5.1.2	H-maser Frequency Standard (& Rb)																	
5.1.3	8 GHz PL Oscillator & Distributor					\$	1		\$	0	\$	0	\$	1	\$	0	\$	1
5.1.4	10 GHz PL Oscillator & Distributor					\$	1		\$	0	\$	0	\$	1	\$	0	\$	1
5.1.5	12 GHz PL Oscillator & Distributor					\$	1		\$	0	\$	0	\$	1	\$	0	\$	1
5.1.6	14 GHz PL Oscillator & Distributor					\$	1		\$	0	\$	0	\$	1	\$	0	\$	1
5.1.7	3.2-5.2 GHz Synthesizer					\$	8		\$	1	\$	1	\$	7	\$	1	\$	8
5.1.8	3.2 -5.2 GHz PLO and Fringe Generator					\$	160		\$	18	\$	21	\$	142	\$	24	\$	161
5.1.9	Sampler Clock 4 GHz PL Osc & Distributor					\$	1		\$	0	\$	0	\$	1	\$	0	\$	1
5.1.10	LO Ref Generator					\$	2		\$	0	\$	0	\$	2	\$	0	\$	2
5.1.11	LO Ref Distributor - Control Bldg					\$	1		\$	0	\$	0	\$	1	\$	0	\$	1
5.1.12	Microwave Round-trip Phase Measurement					\$	60		\$	7	\$	8	\$	53	\$	9	\$	60
5.1.13	10-15 GHz Frequency Synthesizer					\$	100		\$	11	\$	13	\$	89	\$	15	\$	101
5.1.14	First LO Fringe Generator					\$	20		\$	2	\$	3	\$	18	\$	3	\$	20
5.1.15	16 GHz PL Oscillator					\$	40		\$	4	\$	5	\$	36	\$	6	\$	40
5.1.16	26 GHz PL Oscillator					\$	40		\$	4	\$	5	\$	36	\$	6	\$	40
5.1.17	LO Ref Distributor - Antenna					\$	20		\$	2	\$	3	\$	18	\$	3	\$	20
5.1.18	VXCO Clean-up Loop					\$	20		\$	2	\$	3	\$	18	\$	3	\$	20
5.1.19	Power supply module					\$	60		\$	7	\$	8	\$	53	\$	9	\$	60
5.1.20	Bins / Racks (assemble and test)					\$	16		\$	2	\$	2	\$	14	\$	2	\$	16
5.3	Millimeter LO Drivers		3		\$	29	\$	50		\$	19	\$	79	\$	22	\$	90	
5.3.1	Design and System Integration																	
5.3.2	72-95 GHz Source																	
5.3.2.1	Contract Procurement and Fabrication																	
5.3.2.1.1	YIG-tuned Oscillator																	
5.3.2.1.2	18.00 - 23.75 GHz 10 db Amplifier																	
5.3.2.1.3	18.00 - 23.75 GHz x2 Multiplier																	
5.3.2.1.4	36.0 - 47.5 GHz 10 db Amplifier																	
5.3.2.1.5	36.0 - 47.5 GHz x2 Multiplier																	
5.3.2.1.6	Mount and Tuning circuitry																	
5.3.2.2	Assembly and Test																	
5.3.2.3	Deliver 72 - 95 GHz LO Sources																	
5.3.2.3.1	Deliver Modules #1-6																	
5.3.2.3.2	Deliver Modules #7-24																	
5.3.2.3.3	Deliver Modules #25-40																	
5.3.3	100-120 GHz Source																	
5.3.3.1	Contract Procurement and Fabrication																	
5.3.3.1.1	YIG-tuned Oscillator																	
5.3.3.1.2	25.00 - 30.00 GHz 10 db Amplifier																	
5.3.3.1.3	15.00 - 30.00 GHz x2 Multiplier																	
5.3.3.1.4	50.0 - 60.0 GHz 10 db Amplifier																	
5.3.3.1.5	50-60 GHz x2 Multiplier																	
5.3.3.1.6	Mount and Tuning circuitry																	
5.3.3.2	Assembly and Test																	
5.3.3.3	Deliver 100 - 120 GHz LO Sources																	
5.3.3.3.1	Deliver Modules #1-3																	
5.3.3.3.2	Deliver Modules #4-21																	
5.3.3.3.3	Deliver Modules #22-40																	

5.3.4	87 - 108 GHz Source			3	\$	29			\$	4	\$	29	\$	5	\$	33
5.3.4.1	Contract Procurement and Fabrication															
5.3.4.1.1	YIG-tuned Oscillator															
5.3.4.1.2	21.75-27.00 GHz 10 db Amplifier															
5.3.4.1.3	21.75-27.00 GHz x2 Multiplier															
5.3.4.1.4	43.5-54.0 GHz 10 db Amplifier															
5.3.4.1.5	43.5-54.0 GHz x2 Multiplier															
5.3.4.1.6	Mount and Tuning Circuitry															
5.3.4.2	Assembly and Test															
5.3.4.3	Deliver 87 - 108 GHz LO Sources															
5.3.4.3.1	Deliver Modules #1-6															
5.3.4.3.2	Deliver Modules #7-20															
5.3.4.3.3	Deliver Modules #21-35															
5.3.4.3.4	Deliver Modules #36-40															
5.3.5	65 - 85 GHz Source			3	\$	29			\$	4	\$	29	\$	5	\$	33
5.3.5.1	Contract Procurement and Fabrication															
5.3.5.1.1	YIG-tuned Oscillator															
5.3.5.1.2	16.25-21.25 GHz 10 db Amplifier															
5.3.5.1.3	16.25-21.25 GHz x2 Multiplier															
5.3.5.1.4	32.5-42.5 GHz 10 db Amplifier															
5.3.5.1.5	32.5-42.5 GHz x2 Multiplier															
5.3.5.1.6	Mount and Tuning Circuitry															
5.3.5.2	Assembly and Test															
5.3.5.3	Deliver 65 - 85 GHz LO Sources															
5.3.5.3.1	Deliver Modules #1-6															
5.3.5.3.2	Deliver Modules #7-20															
5.3.5.3.3	Deliver Modules #21-35															
5.3.5.3.4	Deliver Modules #36-40															
5.4	Millimeter LO Multiplier Chains			2	\$	20			\$	3	\$	20	\$	3	\$	22
5.4.1	Design and System Integration															
5.4.2	211 - 275 GHz Receiver LO															
5.4.2.1	Contract Fabrication															
5.4.2.1.1	X3 Diode for 72-95 GHz Source															
5.4.2.1.2	Machine Mount															
5.4.2.1.3	Bias and Control circuits															
5.4.2.2	Assemble Multiplier and Test															
5.4.2.3	Integrate Source and Multiplier; test															
5.4.2.4	Deliver 211-275 GHz Rcvr LO Modules															
5.4.2.4.1	Deliver Modules #1-3															
5.4.2.4.2	Deliver Modules #4-21															
5.4.2.4.3	Deliver Modules #22-40															
5.4.3	602 - 720 GHz Receiver LO															
5.4.3.1	Contract Fabrication															
5.4.3.1.1	X2 Diode for 100-120 GHz Source															
5.4.3.1.2	X3 Diode for 200-240 GHz Input															
5.4.3.1.3	Machine Mount															
5.4.3.1.4	Bias and Control circuits															
5.4.3.2	Assemble Multipliers and Test															
5.4.3.3	Integrate Source and Multipliers; test															

5.4.3.4	Deliver 602-720 GHz Rcvr LO Modules																			
5.4.3.4.1	Deliver Modules #1-6																			
5.4.3.4.2	Deliver Modules #7-18																			
5.4.3.4.3	Deliver Modules #19-34																			
5.4.3.4.4	Deliver Modules #35-40																			
5.4.4	275 - 370 GHz Receiver LO																			
5.4.4.1	Contract Fabrication																			
5.4.4.1.1	X2 Diode for 72-95 GHz Source																			
5.4.4.1.2	X2 Diode for 144-190 GHz Input																			
5.4.4.1.3	Machine Mount																			
5.4.4.1.4	Bias and Control Circuits																			
5.4.4.2	Assemble Multipliers and Test																			
5.4.4.3	Integrate Source and Multipliers; test																			
5.4.4.4	Deliver 275-370 GHz Rcvr LO Modules																			
5.4.4.4.1	Deliver Modules #1-6																			
5.4.4.4.2	Deliver Modules #7-27																			
5.4.4.4.3	Deliver Modules #28-40																			
5.4.5	163 - 211 GHz Receiver LO	3	12	\$	88	\$	50		\$	15	\$	24	\$	122	\$	27	\$	139		
5.4.5.1	Contract Fabrication																			
5.4.5.1.1	X2 Diode for 87-108 GHz Source																			
5.4.5.1.2	Machine Mount																			
5.4.5.1.3	Bias and Control Circuits																			
5.4.5.2	Assemble Multiplier and Test																			
5.4.5.3	Integrate Source and Multiplier; test																			
5.4.5.4	Deliver 163 - 211 GHz Rcvr LO Modules																			
5.4.5.4.1	Deliver Modules #1-6																			
5.4.5.4.2	Deliver Modules #7-24																			
5.4.5.4.3	Deliver Modules #25-40																			
5.4.6	385 - 500 GHz Receiver LO	3	12	\$	88	\$	50		\$	15	\$	24	\$	122	\$	27	\$	139		
5.4.6.1	Contract Fabrication																			
5.4.6.1.1	X3 Diode for 65-85 GHz Source																			
5.4.6.1.2	X2 Diode for 130-170 GHz Input																			
5.4.6.1.3	Machine Mount																			
5.4.6.1.4	Bias and Control Circuits																			
5.4.6.2	Assemble Multiplier and test																			
5.4.6.3	Integrate source and Multiplier; test																			
5.4.6.4	Deliver 385-500 GHz Rcvr LO Modules																			
5.4.6.4.1	Deliver Modules #1-6																			
5.4.6.4.2	Deliver Modules #7-24																			
5.4.6.4.3	Deliver Modules #25-40																			
5.4.7	125 - 163 GHz Receiver LO	12	36	\$	293	\$	75		\$	41	\$	54	\$	327	\$	61	\$	370		
5.4.7.1	Contract Fabrication																			
5.4.7.1.1	X2 Diode for 65 - 85 GHz Source																			
5.4.7.1.2	Machine Mount																			
5.4.7.1.3	Bias and Control Circuits																			
5.4.7.2	Assemble Multiplier and test																			
5.4.7.3	Integrate Source and Multiplier; test																			
5.4.7.4	Deliver 125-163 GHz Rcvr LO Modules																			
5.4.7.4.1	Deliver Modules #1-6																			

8.8.4.4	Deliver 1/4 Correlator to MMA site												
8.9	Continued Support												
9	Computing					\$ 400		\$ 120	\$ 400	\$ 136	\$ 453		
9.1	Control Software												
9.1.1	Test Interferometer Control & Analysis												
9.1.2	MMA correlator software												
9.1.3	Multi-antenna & sub-array control												
9.1.4	Operators & Observers interfaces												
9.1.5	Deliver Control Software												
9.1.6	Maintenance	40				\$ 347	\$ 347	\$ -	\$ -	\$ -	\$ -		
9.2	Scheduling												
9.2.1	Static scheduling system												
9.2.2	Dynamic scheduling simulations												
9.2.3	Dynamic scheduling prototype												
9.2.4	Dynamic scheduling implementation	26				\$ 225		\$ 34	\$ 225	\$ 38	\$ 255		
9.2.5	Initial Operations with Dynamic Scheduling												
9.3	Proposal Preparation Software												
9.3.1	Prototype												
9.3.2	Production version	10				\$ 87		\$ 13	\$ 87	\$ 15	\$ 98		
9.4	Image Pipeline												
9.4.1	Automated calibration & imaging heuristics												
9.4.2	Prototype image pipeline												
9.4.3	Parallelization studies and implementation												
9.4.4	Initial Image Pipeline Operations												
9.4.5	Production image pipeline	20				\$ 173		\$ 26	\$ 173	\$ 29	\$ 196		
9.5	Archiving												
9.5.1	Prototype distributed archive												
9.5.2	Evaluate storage hardware												
9.5.3	Production archive	20				\$ 173		\$ 26	\$ 173	\$ 29	\$ 196		
9.5.4	Data Archive operational												
9.6	Post-processing												
9.6.1	Define MMA Data formats												
9.6.2	MMA filler & format conversions												
9.6.3	MMA-specific calibrations												
9.6.4	MMA Post-processing begins												
9.6.5	Maintenance	12				\$ 104	\$ 104	\$ -	\$ -	\$ -	\$ -		
10	System Integration												
10.4	Test Interferometer Site Preparation												
10.4.1	Complete Office and Lab Space Preparation												
10.4.2	Cabling												
10.4.3	Test Interferometer Site Complete												
10.10.4	Prototype Antenna Outfitting												
10.10.4.1	Cabling												
10.10.4.2	Instrumentation												
10.10.4.3	Eval. Rcvr. #1 / Ant. #1 Integration												
10.10.4.4	Antenna #1 Outfitting Complete												
10.10.5	Integration Holography System/Antenna												
10.10.6	Integration Metrology/Antenna												
10.10.7	Antenna #1 Integration & Testing												

10.10.8	Prot. Rcvr. Test & Evaluation																		
10.10.9	Antenna #2 Outfitting																		
10.10.9.1	Cabling																		
10.10.9.2	Instrumentation																		
10.10.9.3	Eval. Rcvr. #2 / Ant. #2 Integration																		
10.10.9.4	Antenna #2 Outfitting Complete																		
10.11	Test Interferometer																		
10.11.1	Antenna Evaluation & Characterization																		
10.11.1.1	Antenna Verification																		
10.11.1.4	Holography																		
10.11.1.5	Beam and Sidelobes																		
10.11.1.6	Gain vs. Elevation: Spillover Temp																		
10.11.1.7	Effect of Sun in & Near the Beam																		
10.11.2	Engineering Recommendations re Prod. Ant.																		
10.11.3	Revise Interface Specifications																		
10.11.5	Operations Personnel Training																		
10.11.5.1	Recruit Initial Chile Ops Staff																		
10.11.5.2	Array Operations																		
10.11.5.3	Engineering Maintenance																		
10.11.5.4	Scientific Support & Analysis																		
10.12.2	Relocate Ops Staff to Chile																		
10.8.4.6	Start On-site Operations																		
10.12	Disassemble Test Interferometer																		
10.12.1	Prepare & Ship Antenna #1, #2																		
10.12.3	Restore Facilities at VLA Site																		
10.13	On Site System Integration		48		48	\$	702		\$	702		\$	-	\$	-	\$	-	\$	-
11	Calibration and Imaging																		
11.1	Radiometric Phase Design & Prototype																		
11.1.1	Complete 183GHz Phase Mon Prototype																		
11.1.2	Demo 183 GHz Phase Monitor Radiometer on-Site																		
11.1.3	Design Refinement																		
11.1.4	Release Phase Mon Radiometer for manufacture																		
11.2	Production Fab of Phase Monitor Radiometer				18	\$	88		\$	13		\$	88		\$	15		\$	99
11.2.1	Contract Subassembly Fabrication																		
11.2.1.1	Radiometer & Local Oscillator																		
11.2.1.2	Spectrometer																		
11.2.1.3	Feed, Window, lens, instrumentation																		
11.2.1.4	M/C Interface																		
11.2.2	Assembly & Test																		
11.2.3	Deliver Production Radiometers																		
11.2.4	Integration in Receiver Package																		
11.2.5	Verification on-Site				3	\$	15		\$	2		\$	15		\$	2		\$	17
11.3	Production Fabrication of Dual-load Amp Cal Sys																		
11.3.1	Design Refinement																		
11.3.2	Release Phase Mon Radiometer for manufacture																		
11.3.3	Contract Subassembly																		
11.3.3.1	Machining																		
11.3.3.2	Load Fabrication																		
11.3.3.3	Motors, Servo																		
11.3.3.4	M/C Interface																		
11.3.4	Assembly & Test																		

11.3.5	Integration on Production Antennas												
11.4	Imaging Studies & Project Support	72				\$ 585		\$ 585		\$ -	\$ -	\$ -	\$ -
11.5	Imaging Algorithm Development	8	4			\$ 100			\$ 15	\$ 100	\$ 17	\$ 113	
TOTALS						\$ 9,774	\$ 31,081	\$ 1,952	\$ 12,603	\$ 6,296	\$ 26,301	\$ 7,123	\$ 29,757

Millimeter Array Construction 2007

WBS	Name	Scientists Work-Months	Programmer Work-Months	Engineers Work-Months	Technicians Work-Months	Personnel Cost	Materials and Supplies	Transfer to Operations	Adjustment to Scope	Contingency	Sum Cost	Inflated Contingency	Inflated Sum
1	Administration												
1.1	Project Management	72			48	\$ 819		\$ 215		\$ 91	\$ 605	\$ 105	\$ 701
1.1.1	Management, Planning, and Oversight						\$ 700			\$ 105	\$ 700	\$ 122	\$ 812
1.1.2	Business Operations						\$ 100			\$ 15	\$ 100	\$ 17	\$ 116
1.1.3	Chilean Operations						\$ 50			\$ 8	\$ 50	\$ 9	\$ 58
1.1.4	Safety and Health												
1.1.5	Personnel												
1.1.6	Project Science Office												
1.1.7	AUI Management						\$ 350			\$ -	\$ 350	\$ -	\$ 406
1.2	Engineering			24	12	\$ 293	\$ 20			\$ 47	\$ 313	\$ 54	\$ 362
1.2.1	System Engineering--Phase II												
1.2.2	Documentation System												
1.2.3	Production Engineering												
1.3	US Facilities												
1.3.1	CDL Permanent Facilities												
1.3.2	Manufacturing Facilities						\$ 100			\$ 15	\$ 100	\$ 17	\$ 116
1.3.3	Common Infrastructure						\$ 200			\$ 30	\$ 200	\$ 35	\$ 232
2	Site Development			12		\$ 117	\$ 50			\$ 25	\$ 167	\$ 29	\$ 194
2.1	Review Legalities Regarding Array and OSF Sites												
2.2	Maintain Mining claims												
2.3	Contract A&E Studies												
2.4	Hire Construction Manager for Chile												
2.5	Array Site												
2.5.1	Prepare Site Development Bid Packages												
2.5.1.1	Prepare Package for Array Site												
2.5.1.2	Review Bid Packages												
2.5.1.3	Bid Civil Works Construction												
2.5.2	Evaluate Array Site Bid Response												
2.5.2.1	Review Bids												
2.5.2.2	Recommend Contractors												
2.5.2.3	Award Array Site Contracts												
2.5.3	Contract Array Site Civil Works												
2.5.3.1	Array Site												
2.5.3.2	Inspect Completed Site Constr												
2.5.3.3	Accept Site Facility												
2.6	Operations Support Facility												
2.6.1	Prepare OSF Bid Packages												
2.6.1.1	Prepare Package for OSF												
2.6.1.2	Review Bid Packages												
2.6.1.3	Bid Civil Works Construction												
2.6.2	Evaluate OSF Bid Response												
2.6.2.1	Review Bids												
2.6.2.2	Recommend Contractors												
2.6.2.3	Award Contracts												

3.72.1	Outfit & Verify Ant #33 at OSF		2	4	\$	39			\$	39	\$	-	\$	-	\$	-	\$	-
3.72.2	Move, Install and Verify Ant #33 on Site		1	1	\$	15			\$	15	\$	-	\$	-	\$	-	\$	-
3.73	Accept Antenna #34 at OSF		1.5		\$	15			\$	15	\$	-	\$	-	\$	-	\$	-
3.74	Prepare Antenna #34																	
3.74.1	Outfit & Verify Ant #34 at OSF		2	4	\$	39			\$	39	\$	-	\$	-	\$	-	\$	-
3.74.2	Move, Install and Verify Ant #34 on Site		1	1	\$	15			\$	15	\$	-	\$	-	\$	-	\$	-
3.75	Accept Antenna #35 at OSF		1.5		\$	15			\$	15	\$	-	\$	-	\$	-	\$	-
3.76	Prepare Antenna #35																	
3.76.1	Outfit & Verify Ant #35 at OSF		2	4	\$	39			\$	39	\$	-	\$	-	\$	-	\$	-
3.76.2	Move, Install & Verify Ant #35 on Site		1	1	\$	15			\$	15	\$	-	\$	-	\$	-	\$	-
3.77	Accept Antenna #36 at OSF		1.5		\$	15			\$	15	\$	-	\$	-	\$	-	\$	-
3.78	Prepare Antenna #36																	
3.78.1	Outfit & Verify Ant #36 at OSF		2	4	\$	39			\$	39	\$	-	\$	-	\$	-	\$	-
3.78.2	Move, Install & Verify Ant #36 on Site		1	1	\$	15			\$	15	\$	-	\$	-	\$	-	\$	-
3.79	Prepare Antenna #1																	
3.79.1	Antenna #1 Reassembled at OSF		1.5		\$	15					2	\$	15	\$	3	\$	17	
3.79.2	Outfit & Verify Ant #1 at OSF		2	4	\$	39			\$	-	\$	6	\$	39	\$	7	\$	45
3.79.3	Move, Install & Verify Ant #1 on Site		1	1	\$	15			\$	-	\$	2	\$	15	\$	3	\$	17
3.80	Prepare Antenna #2																	
3.80.1	Antenna #2 Reassembled at OSF		1.5		\$	15					2	\$	15	\$	3	\$	17	
3.80.2	Outfit & Verify Ant #2 at OSF		2	4	\$	39					6	\$	39	\$	7	\$	45	
3.80.3	Move, Install & Verify Ant #2 on Site		1	1	\$	15					2	\$	15	\$	3	\$	17	
3.81	Antenna Transporter																	
3.81.1	Contract for Transporter #1, move to Site																	
3.81.2	Contract for Transporters #2, #3																	
3.81.3	Accept Transporters #2, #3 at OSF																	
4	Receivers																	
4.1	Receiver Package																	
4.1.1	Prototype Production Receiver Cryogenics																	
4.1.1.1	CDR: Cryogenics Development																	
4.1.1.2	Construct & test prototype cryogenics																	
4.1.1.3	Deliver Prototype Cryogenics Subsystem																	
4.1.2	Prototype Production Receiver Package																	
4.1.2.1	Prototype Receiver Package Integration																	
4.1.2.2	Prot. Rcvr. Pckg Lab Test & Evaluation																	
4.1.2.3	Complete Prototype MMA Receiver Package																	
4.1.3	MMA Rcvr Pckg Design Refinement																	
4.1.4	Documentation																	
4.1.5	Release MMA Receiver Pckg for manufacture																	
4.1.6	Contract for Receiver Pckg Subassemblies																	
4.1.6.1	Machine Dewars			30	\$	146	\$	50	\$	22	\$	30	\$	174	\$	35	\$	202
4.1.6.2	Fabricate Cryogenics subsystems		6	24	\$	176	\$	240	\$	46	\$	84	\$	369	\$	98	\$	428
4.1.6.3	Fabricate windows, IR filters, etc		6	30	\$	205	\$	100	\$	34	\$	51	\$	271	\$	59	\$	314
4.1.7	Accept Receiver Pckg Subassemblies																	
4.1.7.1	Subassemblies #1-6																	
4.1.7.2	Subassemblies #7-16																	
4.1.7.3	Subassemblies #17-26																	
4.1.7.4	Subassemblies #27-36																	
4.1.7.5	Subassemblies #37-40																	

4.1.8	Fab Rcvr Pckg Instrumentation & Electronics			3	12	\$ 88	\$ 75	\$ 18	\$ 30	\$ 145	\$ 35	\$ 168
4.1.9	Fabricate Receiver Inserts			18	30	\$ 322	\$ 100	\$ 47	\$ 64	\$ 375	\$ 74	\$ 435
4.1.10	Assemble Receiver Package											
4.1.10.1	Integrate Rcvr Instrumentation & subass'y			12	48	\$ 351	\$ 80	\$ 48	\$ 62	\$ 383	\$ 72	\$ 444
4.1.10.2	Deliver Receiver Package #1-6											
4.1.10.3	Deliver Receiver Package #7-16											
4.1.10.4	Deliver Receiver Package #17-26											
4.1.10.5	Deliver Receiver Package #27-36											
4.1.10.6	Deliver Receiver Package #37-40											
4.2	SIS Receiver Modules											
4.2.1	211-275 GHz Module											
4.2.1.1	SIS Mixer											
4.2.1.1.1	Design, Fab and Test Mixer Design											
4.2.1.1.2	Deliver Production Design											
4.2.1.1.3	Fabricate Production Mixers											
4.2.1.2	Design & Verify Optics											
4.2.1.3	Design Module											
4.2.1.4	Contract Fabrication											
4.2.1.4.1	Machine Mixer Blocks, Feed, WG, Lenses											
4.2.1.4.2	Assemble Modules											
4.2.1.5	Install SIS Mixer & Test Modules											
4.2.1.6	Deliver 211-275 GHz Receiver Modules											
4.2.1.6.1	Deliver Modules #1-7											
4.2.1.6.2	Deliver Modules #8-26											
4.2.1.6.3	Deliver Modules #27-40											
4.2.2	602-720 GHz Module											
4.2.2.1	SIS Mixer											
4.2.2.1.1	Design, Fabricate and Test Mixer Design											
4.2.2.1.2	Deliver Production Design											
4.2.2.1.3	Fabricate Production Mixers											
4.2.2.2	Design & Verify Optics											
4.2.2.3	Design Module											
4.2.2.4	Contract Fabrication											
4.2.2.4.1	Machine Mixer Blocks, Feed, WG, Lenses											
4.2.2.4.2	Assemble Modules											
4.2.2.5	Install SIS Mixer and Test Modules											
4.2.2.6	Deliver 602-720 GHz Receiver Modules											
4.2.2.6.1	Deliver Modules #1-7											
4.2.2.6.2	Deliver Modules #8-26											
4.2.2.6.3	Deliver Modules #27-40											
4.2.3	275-370 GHz Receiver Module											
4.2.3.1	SIS Mixer											
4.2.3.1.1	Design, Fabricate and Test Mixer Design											
4.2.3.1.2	Deliver Production Design											
4.2.3.1.3	Fabricate Production Mixers											
4.2.3.2	Design & Verify Optics											
4.2.3.3	Design Module											
4.2.3.4	Contract Fabrication											
4.2.3.4.1	Machine Mixer Blocks, Feed, WG, Lenses											
4.2.3.4.2	Assemble Modules											

4.2.3.5	Install SIS Mixer and Test Modules																					
4.2.3.6	Deliver 275-370 GHz Receiver Module																					
4.2.3.6.1	Deliver Modules #1-5																					
4.2.3.6.2	Deliver Modules #6-30																					
4.2.3.6.3	Deliver Modules #30-40																					
4.2.4	91-119 GHz Receiver Module																					
4.2.4.1	SIS Mixer																					
4.2.4.1.1	Design, Fabricate & Test Mixer Design																					
4.2.4.1.2	Deliver Production Design																					
4.2.4.1.3	Fabricate Production Mixers																					
4.2.4.2	Design & Verify Optics																					
4.2.4.3	Design Module																					
4.2.4.4	Contract Fabrication																					
4.2.4.4.1	Machine Mixer Blocks, Feed, WG, Lenses																					
4.2.4.4.2	Assemble Modules																					
4.2.4.5	Install SIS Mixer and Test Modules																					
4.2.4.6	Deliver 91-119 GHz Receiver Modules																					
4.2.4.6.1	Deliver Modules #1-5																					
4.2.4.6.2	Deliver Modules #6-30																					
4.2.4.6.3	Deliver Modules # 31-40																					
4.2.5	163-211 GHz Receiver Module																					
4.2.5.1	SIS Mixer																					
4.2.5.1.1	Design, Fabricate & Test Mixer Design																					
4.2.5.1.2	Deliver Production Design																					
4.2.5.1.3	Fabricate Production Mixers																					
4.2.5.2	Design & Verify Optics																					
4.2.5.3	Design Module																					
4.2.5.4	Contract Fabrication																					
4.2.5.4.1	Machine Mixer Blocks, Feed, WG, Lenses																					
4.2.5.4.2	Assemble Modules																					
4.2.5.5	Install SIS Mixer and Test				6		12	\$	117	\$	20		\$	15	\$	19	\$	122	\$	22	\$	141
4.2.5.6	Deliver 163-211 GHz Receiver Modules																					
4.2.5.6.1	Deliver Modules #1-5																					
4.2.5.6.2	Deliver Modules #6-30																					
4.2.5.6.3	Deliver Modules #31-40																					
4.2.6	385-500 GHz Receiver Module																					
4.2.6.1	SIS Mixer																					
4.2.6.1.1	Design, Fabricate & Test Mixer Design																					
4.2.6.1.2	Deliver Production Design																					
4.2.6.1.3	Fabricate Production Mixers																					
4.2.6.2	Design and Verify Optics																					
4.2.6.3	Design Module																					
4.2.6.4	Contract Fabrication																					
4.2.6.4.1	Machine Mixer Blocks, Feed, WG, Lenses																					
4.2.6.4.2	Assemble Modules																					
4.2.6.5	Install SIS Mixer and Test				6		12	\$	117	\$	20		\$	137	\$	-	\$	-	\$	-	\$	-
4.2.6.6	Deliver 385-500 GHz Receiver Modules																					
4.2.6.6.1	Deliver Modules #1-5																					
4.2.6.6.2	Deliver Modules #6-30																					
4.2.6.6.3	Deliver Modules #31-40																					

4.2.7	125-163 GHz Receiver Module																				
4.2.7.1	SIS Mixer																				
4.2.7.1.1	Design, Fabricate & Test Mixer Design																				
4.2.7.1.2	Deliver Production Design																				
4.2.7.1.3	Fabricate Production Mixers																				
4.2.7.2	Design & Verify Optics																				
4.2.7.3	Design Module																				
4.2.7.4	Contract Fabrication																				
4.2.7.4.1	Machine Mixer Blocks, Feed, WG, Lenses																				
4.2.7.4.2	Assemble Modules																				
4.2.7.5	Install SIS Mixer and Test	24			48	\$	468	\$	50			\$	58	\$	68	\$	460	\$	79	\$	534
4.2.7.6	Deliver 125-163 GHz Receiver Modules																				
4.2.7.6.1	Deliver 125-163 GHz Modules #1-5																				
4.2.7.6.2	Deliver 125-163 GHz Modules #6-30																				
4.2.7.6.3	Deliver 125-163 GHz Modules #31-40																				
4.3	HFET Receiver Modules																				
4.3.1	Contract for HFET Wafer																				
4.3.2	Receive Diced HFET Wafer																				
4.3.3	33-45 GHz Module																				
4.3.3.1	Design Module																				
4.3.3.2	Design & Verify Optics																				
4.3.3.3	Contract Fabrication																				
4.3.3.3.1	Machine Blocks, Feed, WG, Lenses																				
4.3.3.3.2	Assemble Modules																				
4.3.3.3.3	Flip-in Mirror																				
4.3.4	Install HFET & Test Modules																				
4.3.5	Deliver 33-45 GHz Receiver Modules																				
4.3.5.1	Deliver Modules #1-20																				
4.3.5.2	Deliver Modules #21-40																				
4.3.6	67-95 GHz Module																				
4.3.6.1	Design Amplifier																				
4.3.6.2	Design Module																				
4.3.6.3	Design & Verify Optics																				
4.3.6.4	Contract Fabrication																				
4.3.6.4.1	Machine Blocks, Feed, WG, Lenses																				
4.3.6.4.2	Assemble Modules																				
4.3.6.5	Install HFET & Test Modules																				
4.3.6.6	Deliver 67-95 GHz Receiver Modules																				
4.3.6.6.1	Deliver Modules 67-95GHz #1-20																				
4.3.6.6.2	Deliver Modules 67-95GHz #21-40																				
5	LO System																				
5.1	LO Reference: Prototype Systems																				
5.1.1	Deliver: Bench Prototype																				
5.1.2	Testing and Design Refinement																				
5.1.3	Procure/Fab Field Prototypes																				
5.1.4	Deliver: LO Ref Field Prototypes																				
5.1.5	Field Prototype testing and Design Refinement																				
5.1.6	Preproduction Review																				

8.8.4.4	Deliver 1/4 Correlator to MMA site												
8.9	Continued Support												
9	Computing					\$ 150		\$ 45	\$ 150	\$ 52	\$ 174		
9.1	Control Software												
9.1.1	Test Interferometer Control & Analysis												
9.1.2	MMA correlator software												
9.1.3	Multi-antenna & sub-array control												
9.1.4	Operators & Observers interfaces												
9.1.5	Deliver Control Software												
9.1.6	Maintenance	40			\$ 347	\$ 347	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
9.2	Scheduling												
9.2.1	Static scheduling system												
9.2.2	Dynamic scheduling simulations												
9.2.3	Dynamic scheduling prototype												
9.2.4	Dynamic scheduling implementation	26			\$ 225		\$ 34	\$ 225	\$ 39	\$ 261			
9.2.5	Initial Operations with Dynamic Scheduling												
9.3	Proposal Preparation Software												
9.3.1	Prototype												
9.3.2	Production version	10			\$ 87		\$ 13	\$ 87	\$ 15	\$ 101			
9.4	Image Pipeline												
9.4.1	Automated calibration & imaging heuristics												
9.4.2	Prototype image pipeline	40			\$ 347		\$ 52	\$ 347	\$ 60	\$ 402			
9.4.3	Parallelization studies and implementation												
9.4.4	Initial Image Pipeline Operations												
9.4.5	Production image pipeline												
9.5	Archiving												
9.5.1	Prototype distributed archive												
9.5.2	Evaluate storage hardware	6			\$ 52		\$ 8	\$ 52	\$ 9	\$ 60			
9.5.3	Production archive	20			\$ 173		\$ 26	\$ 173	\$ 30	\$ 201			
9.5.4	Data Archive operational												
9.6	Post-processing												
9.6.1	Define MMA Data formats												
9.6.2	MMA filler & format conversions												
9.6.3	MMA-specific calibrations												
9.6.4	MMA Post-processing begins												
9.6.5	Maintenance	12			\$ 104	\$ 104	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -
10	System Integration												
10.4	Test Interferometer Site Preparation												
10.4.1	Complete Office and Lab Space Preparation												
10.4.2	Cabling												
10.4.3	Test Interferometer Site Complete												
10.10.4	Prototype Antenna Outfitting												
10.10.4.1	Cabling												
10.10.4.2	Instrumentation												
10.10.4.3	Eval. Rcvr. #1 / Ant. #1 Integration												
10.10.4.4	Antenna #1 Outfitting Complete												
10.10.5	Integration Holography System/Antenna												
10.10.6	Integration Metrology/Antenna												
10.10.7	Antenna #1 Integration & Testing												

10.10.8	Prot. Rcvr. Test & Evaluation													
10.10.9	Antenna #2 Outfitting													
10.10.9.1	Cabling													
10.10.9.2	Instrumentation													
10.10.9.3	Eval. Rcvr. #2 / Ant. #2 Integration													
10.10.9.4	Antenna #2 Outfitting Complete													
10.11	Test Interferometer													
10.11.1	Antenna Evaluation & Characterization													
10.11.1.1	Antenna Verification													
10.11.1.4	Holography													
10.11.1.5	Beam and Sidelobes													
10.11.1.6	Gain vs. Elevation: Spillover Temp													
10.11.1.7	Effect of Sun in & Near the Beam													
10.11.2	Engineering Recommendations re Prod. Ant.													
10.11.3	Revise Interface Specifications													
10.11.5	Operations Personnel Training													
10.11.5.1	Recruit Initial Chile Ops Staff													
10.11.5.2	Array Operations													
10.11.5.3	Engineering Maintenance													
10.11.5.4	Scientific Support & Analysis													
10.12.2	Relocate Ops Staff to Chile													
10.8.4.6	Start On-site Operations													
10.12	Disassemble Test Interferometer													
10.12.1	Prepare & Ship Antenna #1, #2													
10.12.3	Restore Facilities at VLA Site													
10.13	On Site System Integration		48	48	\$	702	\$	702	\$	-	\$	-	\$	-
11	Calibration and Imaging													
11.1	Radiometric Phase Design & Prototype													
11.1.1	Complete 183GHz Phase Mon Prototype													
11.1.2	Demo 183 GHz Phase Monitor Radiometer on-Site													
11.1.3	Design Refinement													
11.1.4	Release Phase Mon Radiometer for manufacture													
11.2	Production Fab of Phase Monitor Radiometer			18	\$	88	\$	13	\$	88	\$	15	\$	102
11.2.1	Contract Subassembly Fabrication													
11.2.1.1	Radiometer & Local Oscillator													
11.2.1.2	Spectrometer													
11.2.1.3	Feed, Window, lens, instrumentation													
11.2.1.4	M/C Interface													
11.2.2	Assembly & Test													
11.2.3	Deliver Production Radiometers													
11.2.4	Integration in Receiver Package													
11.2.5	Verification on-Site													
11.3	Production Fabrication of Dual-load Amp Cal Sys			3	\$	15	\$	2	\$	15	\$	3	\$	17
11.3.1	Design Refinement													
11.3.2	Release Phase Mon Radiometer for manufacture													
11.3.3	Contract Subassembly													
11.3.3.1	Machining													
11.3.3.2	Load Fabrication													
11.3.3.3	Motors, Servo													
11.3.3.4	M/C Interface													
11.3.4	Assembly & Test													

11.3.5	Integration on Production Antennas												
11.4	Imaging Studies & Project Support	72				\$ 585		\$ 585		\$ -	\$ -	\$ -	\$ -
11.5	Imaging Algorithm Development	8	4			\$ 100				\$ 15	\$ 100	\$ 17	\$ 116
TOTALS						\$ 7,845	\$ 3,973	\$ 2,119	\$ 846	\$ 1,379	\$ 8,853	\$ 1,599	\$ 10,267