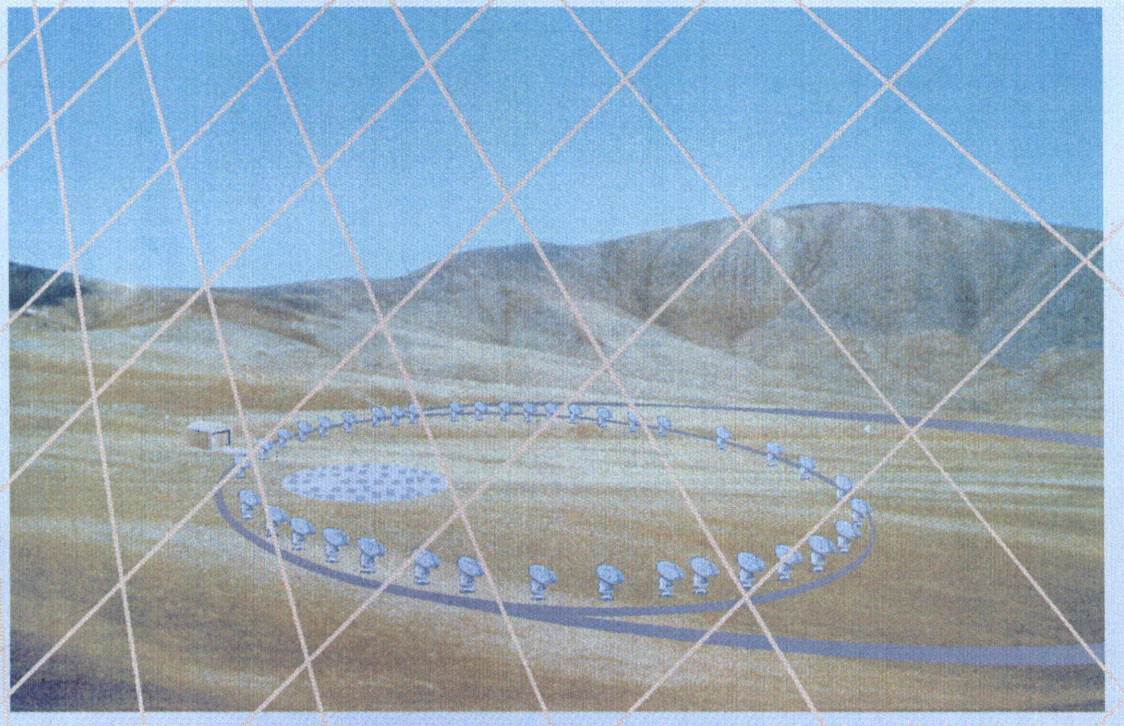
# Millimeter Array

## Construction Cost of the U.S. Reference Project

Addendum
July 1999



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

# Millimeter Array

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**National Radio Astronomy Observatory**
**National Science Foundation**


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## SUMMARY

This document amends the document *Millimeter Array: Construction Cost of the U.S. Reference Project, May 1999.* While it was the intent of the May 99 analysis to cost not only the U.S. Reference Project but also to provide estimates of the cost savings achievable by reducing the scope of the project, it is the intent of this document to provide a cost estimate only and specifically of the MMA U.S. Reference Project. A concise summary of the technical description of the MMA U.S. Reference Project is found on the following page.

Work Breakdown Structure. The WBS for the construction phase of the MMA U.S. Reference Project is presented here. It amends the WBS given in the May document and presents detailed tasking at a still lower level. The WBS provides the overall description of the construction phase of the MMA U.S. Reference Project and lays out the tasking and allocation of resources year-by-year. The WBS provides the framework for the Project Cost determination.

Project Cost. Construction of the MMA U.S. Reference Project would begin in 2001 upon completion of the Design and Development phase. The construction will conclude at the end of calendar year 2007. The cost tables are presented in this document. Costs are estimated for all the WBS tasks with deliverables. The cost summaries given here include year-by-year summaries as well as the Project summary by WBS category. In addition to estimates of the materials needed for each task, and the time of personnel working on the task, estimates are also presented for the contingency associated with each task.

Contingency. The contingency estimate generated for each costed WBS task results from a *bottom-up* computation in which the contingency for each part of a given WBS task is estimated separately and independently; the contingency assigned to a given WBS task is the sum of the contingency assigned to its sub-tasks. The methodology for assigning a bottom-up contingency is described below. This approach differs from that used in the earlier (May 1999) analysis in which a *top-down* estimate for the contingency was made.

Inflation. An estimate of 2.5% inflation over the period 2001-2007 is used here in the cost tables. Since inflation is applied to the sum of the costs of materials, personnel and contingency it potentially has a large effect; this effect is illustrated below for a range of inflation rates.

Glossary. A Glossary of Terms and Acronyms is included below.

# MILLIMETER ARRAY: TECHNICAL SPECIFICATION OF THE U.S. REFERENCE PROJECT

**Array**

| | |
|---|---|
| Number of Antennas | 36 |
| Number of Configurations | 4 |
| Number of Antenna Stations | 130 |
| Frequency Coverage | 30 - 720 GHz |
| Number of 4 K Cryogenic Dewars | 36 in total, one per antenna |
| Number of Receivers | 9 per antenna (all are dual polarization) |
| IF Bandwidth from each antenna | 16 GHz (8 GHz per polarization) |
| Phase Calibration | 183 GHz WVR on each antenna |
| Array Site | Llano de Chajnantor, Chile (5000 m elev) |
| Operations Site | San Pedro de Atacama, Chile |

**Configurations**

| | |
|---|---|
| Compact | 70 m circular |
| Intermediate (2) | 250 m, 900 m circular |
| High Resolution | 3000 m circular |

**Antennas**

| | |
|---|---|
| Diameter | 10 m |
| Surface Precision | < 25 micrometers RSS |
| Pointing Precision | 0."8 RSS (re-pointing every 15 min) |
| Total Power | Instrumented |
| Solar Observing | Capable with no degradation |
| Transportable | By service vehicle over roads |

**Receivers**

| | |
|---|---|
| 28 - 45 GHz HFET | T(Rx) < 20 K |
| 67 - 95 GHz HFET | T(Rx) < 40 K |
| 91 - 119 GHz SIS | T(Rx) < 6*h*nu/k single sideband |
| 125 - 163 GHz SIS | T(Rx) < 6*h*nu/k single sideband |
| 163 - 211 GHz SIS | T(Rx) < 6*h*nu/k single sideband |
| 211 - 275 GHz SIS | T(Rx) < 6*h*nu/k single sideband |
| 275 - 370 GHz SIS | T(Rx) < 6*h*nu/k single sideband |
| 385 - 500 GHz SIS | T(Rx) < 6*h*nu/k single sideband |
| 602 - 720 GHz SIS | T(Rx) < 8*h*nu/k single sideband |

**Correlator**

| | |
|---|---|
| Number of Antenna Inputs | 36 |
| Number of Baselines (cross-correlations) | 630 |
| Analyzed IF Bandwidth | 8 GHz per polarization |
| Spectral Frequency Channels | 4096 per IF |

# MMA U.S. REFERENCE PROJECT

## Using Bottom-up Contingency Estimation

| WBS | TASK | Design and Development Current Year Dollars | Construction 1999 Dollars | Project Totals 1999 Dollars |
|---|---|---|---|---|
| 1 | Administration | $ 3,069.0 | $ 18,344.0 | $ 21,413.0 |
| 2 | Site Development | $ 178.0 | $ 49,681.0 | $ 49,859.0 |
| 3 | Antennas | $ 5,942.0 | $ 101,610.0 | $ 107,552.0 |
| 4 | Receiver System | $ 6,370.0 | $ 43,429.0 | $ 49,799.0 |
| 5 | Local Oscillator | $ 2,636.0 | $ 19,599.0 | $ 22,235.0 |
| 6 | IF System | $ 840.0 | $ 9,368.0 | $ 10,208.0 |
| 7 | FO System | $ 454.0 | $ 10,575.0 | $ 11,029.0 |
| 8 | Correlator | $ 1,183.0 | $ 9,371.0 | $ 10,554.0 |
| 9 | Computing | $ 1,298.0 | $ 6,762.0 | $ 8,060.0 |
| 10 | System Integration | $ 518.0 | $ 3,825.0 | $ 4,343.0 |
| 11 | Calibration and Imaging | $ 1,445.0 | $ 2,575.0 | $ 4,020.0 |
| | ***subtotal*** | **$ 23,933.0** | **$ 275,139.0** | **$ 299,072.0** |
| | Contingency | $ 1,962.0 | $ 67,449.0 | $ 69,411.0 |
| | **TOTAL (k$)** | **$ 25,895.0** | **$ 342,588.0** | **$ 368,483.0** |

# MMA U.S. REFERENCE PROJECT

## Rolled up Contingency

| WBS | TASK | Design and Development Current Year Dollars | Construction 1999 Dollars | Contingency 1999 Dollars | Contingency Percent | Project Totals 1999 Dollars |
|---|---|---|---|---|---|---|
| 1 | Administration | $ 3,069.0 | $ 18,344.0 | $ 2,261.0 | 12% | $ 23,674.0 |
| 2 | Site Development | $ 178.0 | $ 49,681.0 | $ 9,770.0 | 20% | $ 59,629.0 |
| 3 | Antennas | $ 7,904.0 | $ 101,610.0 | $ 27,010.0 | 27% | $ 136,524.0 |
| 4 | Receiver System | $ 6,370.0 | $ 43,429.0 | $ 12,106.0 | 28% | $ 61,905.0 |
| 5 | Local Oscillator | $ 2,636.0 | $ 19,599.0 | $ 5,321.0 | 27% | $ 27,556.0 |
| 6 | IF System | $ 840.0 | $ 9,368.0 | $ 1,474.0 | 16% | $ 11,682.0 |
| 7 | FO System | $ 454.0 | $ 10,575.0 | $ 3,452.0 | 33% | $ 14,481.0 |
| 8 | Correlator | $ 1,183.0 | $ 9,371.0 | $ 2,607.0 | 28% | $ 13,161.0 |
| 9 | Computing | $ 1,298.0 | $ 6,762.0 | $ 2,210.0 | 33% | $ 10,270.0 |
| 10 | System Integration | $ 518.0 | $ 3,825.0 | $ 1,022.0 | 27% | $ 5,365.0 |
| 11 | Calibration and Imaging | $ 1,445.0 | $ 2,575.0 | $ 216.0 | 8% | $ 4,236.0 |
| | **TOTAL** | **$ 25,895.0** | **$ 275,139.0** | **$ 67,449.0** | | **$ 368,483.0** |

# MMA Cost Estimation (1999-June-09)

## Basic Cost Estimation

Material, labor, and contract costs will be estimated for each WBS task. Labor rates will be based on labor categories supplied by individual cost estimators combined with historical cost experience at NRAO.

**Labor Categories**

| | | | |
|---|---|---|---|
| SC | Scientist | EN | Engineer |
| PR | Programmer | TE | Technician & Support |

## Contingency Cost Estimation

Contingency cost estimation and analysis shall be performed for each task in the MMA WBS. The results of this analysis will be related to a contingency which shall be listed for each WBS task.

## Contingency Methodology

Estimators shall evaluate the technical, cost and schedule risk for every WBS task. For technical risk, the value of 1 implies "normal industry supplied off the shelf item" and 15 is reserved for components "way beyond the current state of the art." For cost risk values, 1 is used to indicate vendor quote or catalog price for a specific item" and 15 is used for estimates where no data is available. Schedule risk factors range from 2 to 8. The technical risk factor is multiplied by a risk percentage which is categorized below. The resulting percentages are added together to establish the total contingency for a particular WBS task. The minimum contingency percentage under this approach is 5% and the maximum is 98%.

There may be special cases where the parameter limitations defined above are inappropriate. Some high risk elements may deserve contingencies greater than 98%. In these cases, the discretion of the estimator, higher values may be used. Justification for these cases must be provided in the estimator's basis of estimate.

Estimators should use 1999 dollars for their estimates.

**Definition of Risk Factors**

| Risk Factor | Technical | Cost | Schedule |
|---|---|---|---|
| 1 | Existing design and off the shelf hardware. | Off the shelf or catalog item. | not used |
| 2 | Minor modifications to an existing design. | Vendor quote from established drawings. | No schedule impact on any other item. |
| 3 | Extensive modifications to an existing design. | Vendor quote with some design sketches. | not used |
| 4 | New design within established product line. | In-house estimate for item within current product line. | Delays completion of non-critical path subsystem item. |
| 6 | New design different from established product line. Existing technology. | In-house estimate for item with minimal company experience but related to existing capabilities. | not used |
| 8 | New design. Requires some R&D development but does not advance the state-of-the-art. | In-house estimate for item with minimal company experience and minimal in-house capability. | Delays completion of critical path subsystem item. |
| 10 | New design. Development of new technology which advances the state-of-the-art. | Top down estimate from analogous programs. | not used |
| 15 | New design way beyond the current state-of-the-art. | Engineering judgement. | not used |

**Multipliers for Contingency/Risk Calculation**

| | Condition | Risk Percentage |
|---|---|---|
| Technical | Design **or** mfg concerns only | 2% |
| | Design **and** mfg concerns | 4% |
| Cost | Material cost **or** labor rate concern | 1% |
| | Material **and** labor rate concern | 2% |
| Schedule | | 1% |

# MMA U.S. REFERENCE PROJECT

## Cost Impact of Inflation

| Assumed Annual Inflation Rate | Aggregate Project Cost Increment (k$) | |
|---|---|---|
| 1.5% | $ 25,756.0 | |
| 2.0% | $ 36,109.0 | |
| 2.5% | $ 45,688.0 | * Note |
| 3.0% | $ 55,498.0 | |

Note: 2.5% Adopted for use in the Cost Summary

# GLOSSARY OF TERMS AND ACRONYMS

| | |
|---|---|
| ADC | Analog to digital converter |
| ALMA | Atacama Large Millimeter Array |
| Atacama | The desert region that dominates northern Chile |
| AUI | Associated Universities, Inc. |
| Backend | Processing hardware following all amplification stages |
| BBC | Baseband Converter |
| Bias | Sustained voltage or current needed for device operation |
| BS | Base station, another term for OSF |
| CAN | Computer Area Network |
| CDL | Central Development Laboratory (NRAO) |
| CEB | Central electronics building (on array site) |
| C-M | Control-Monitoring function |
| CNC | Computer Numerically Controlled (machine) |
| CVS | Code Validation System (for software version control) |
| CW | Continuous wave |
| D&D | Design and Development |
| Demux | Demultiplexor |
| Detector | The first stage amplifier or mixer device in its mount |
| Dewar | Cryogenic vessel containing the receiver inserts |
| DMM | Digital multimeter |
| DWDM | Digital wavelength division multiplexing |
| Feedhorn | Machined conical optical focus for the received signals |
| FFT | Fast fourier transform |
| FIR | Finite impulse response |
| FITS | Flexible Image Transport System |
| FO | Fiber optics |
| GHz | GigaHertz (10^9 Hertz) |
| HEMT | High Electron Mobility Transistor (also known as HFET) |
| HFET | Heterostructure Field Effect Transistor (also HEMT) |
| Holography | Interferometric relative phase recovery system for measurement of antenna surface figure |
| HP | Hewlett-Packard, electronics manufacturer |
| IF | Intermediate frequency |
| InP | Indium Phosphide |
| Insert | Receiver at one frequency band. Consists of the detector module, second stage amplifier and LO port |
| IR | Infrared |
| Jig | Fixture to aid assembly of component parts |
| JT System | Joule-Thompson expansion system for cryogenic refrigerator |
| LHe | Liquid helium |
| LN2 | Liquid nitrogen |
| LNA | Low noise amplifier |
| LO | Local oscillator |

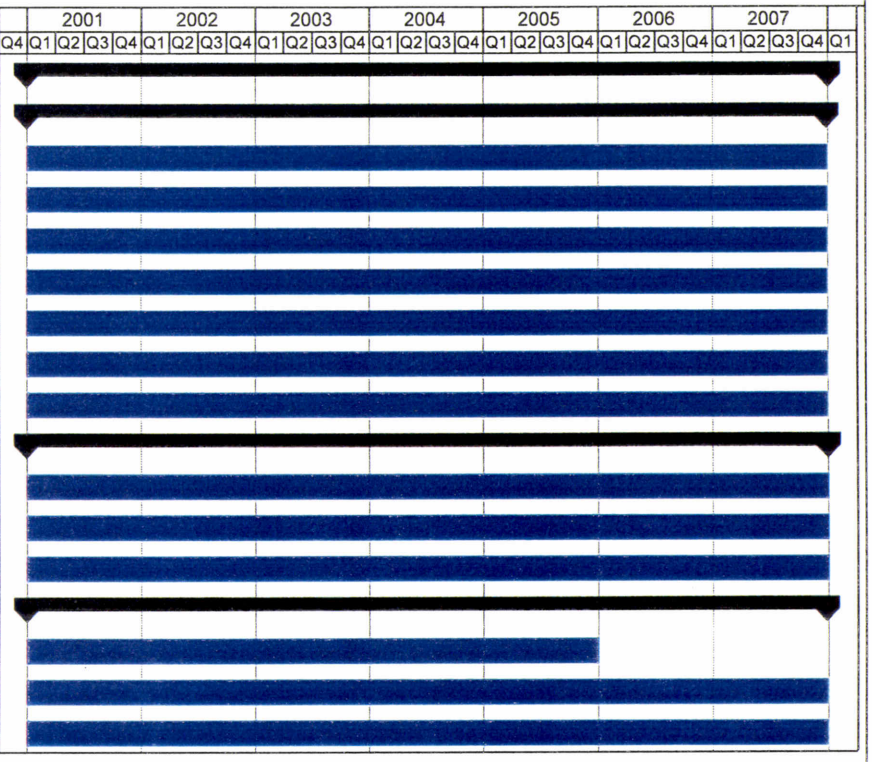
| | |
|---|---|
| LPF | Low pass filter |
| LST | Local Sidereal Time |
| LTA | Long term accumulator |
| M/C | Monitor and control |
| MMA | Millimeter Array |
| MMAOC | MMA Oversight Committee, a NSF committee |
| MMIC | Monolithic Millimeter-wave Integrated Circuit |
| Module | Integrated assembly of discrete devices |
| Mux | Multiplexer |
| NRAO | National Radio Astronomy Observatory |
| NSF | National Science Foundation |
| OMT | Orthomode transducer. Waveguide device to split polarizations |
| OSF | Operations Support Facility, the MMA operations center in San Pedro de Atacama, Chile |
| PC | Personal computer |
| PCB | PC board |
| PL | Phase lock |
| PLO | Phase locked oscillator |
| PM | Polarization maintaining |
| PPR | Prototype Production Receiver |
| PPRC | Prototype Production Receiver Cryogenics |
| Quasi-optical | RF components functionally similar to optical components |
| RF | Radio frequency |
| RFI | Radio frequency interference |
| RT | Round trip |
| Rx | Receiver |
| SIS | Superconductor-Insulator-Superconductor, mixer device |
| Stony Brook | State University of New York at Stony Brook |
| Tek | Tektronix, electronics manufacturer |
| Transporter | Vehicle to move and reposition the antennas |
| Tx | Transmitter |
| UVA | University of Virginia |
| UV-data | Source visibility data in the fourier plane |
| UV-plane | Image fourier plane |
| VLBI | Very Long Baseline Interferometry |
| VME | Tradename of Wind River Systems, Inc. product |
| VXCO | Voltage-controlled oscillator |
| WBS | Work Breakdown Structure |
| WVR | Water Vapor Radiometer |
| YIG | Yttrium-Indium-Germanium (fundamental oscillator) |

# Work Breakdown Structure

# MMA Construction Tasks

**All Tasks selected**

| WBS (f) | Task | Start | Finish | CostData? |
|---|---|---|---|---|
| 1 | **Administration** | 2001-01-01 | 2008-01-01 | No |
| 1.1 | **Project Management** | 2001-01-01 | 2007-12-27 | Yes |
| 1.1.1 | Management, Planning, and Oversight | 2001-01-01 | 2007-12-27 | Yes |
| 1.1.2 | Business Operations | 2001-01-01 | 2007-12-27 | Yes |
| 1.1.3 | Chilean Operations | 2001-01-01 | 2007-12-27 | Yes |
| 1.1.4 | Safety and Health | 2001-01-01 | 2007-12-27 | Yes |
| 1.1.5 | Personnel | 2001-01-01 | 2007-12-27 | Yes |
| 1.1.6 | Project Science Office | 2001-01-01 | 2007-12-27 | Yes |
| 1.1.7 | AUI Management | 2001-01-01 | 2007-12-27 | Yes |
| 1.2 | **Engineering** | 2001-01-01 | 2008-01-01 | Yes |
| 1.2.1 | System Engineering--Phase II | 2001-01-01 | 2008-01-01 | Yes |
| 1.2.2 | Documentation System | 2001-01-01 | 2008-01-01 | Yes |
| 1.2.3 | Production Engineering | 2001-01-01 | 2008-01-01 | Yes |
| 1.3 | **US Facilities** | 2001-01-01 | 2007-12-27 | Yes |
| 1.3.1 | CDL Permanent Facilities | 2001-01-01 | 2005-12-29 | Yes |
| 1.3.2 | Manufacturing Facilities | 2001-01-01 | 2007-12-27 | Yes |
| 1.3.3 | Common Infrastructure | 2001-01-01 | 2007-12-27 | Yes |

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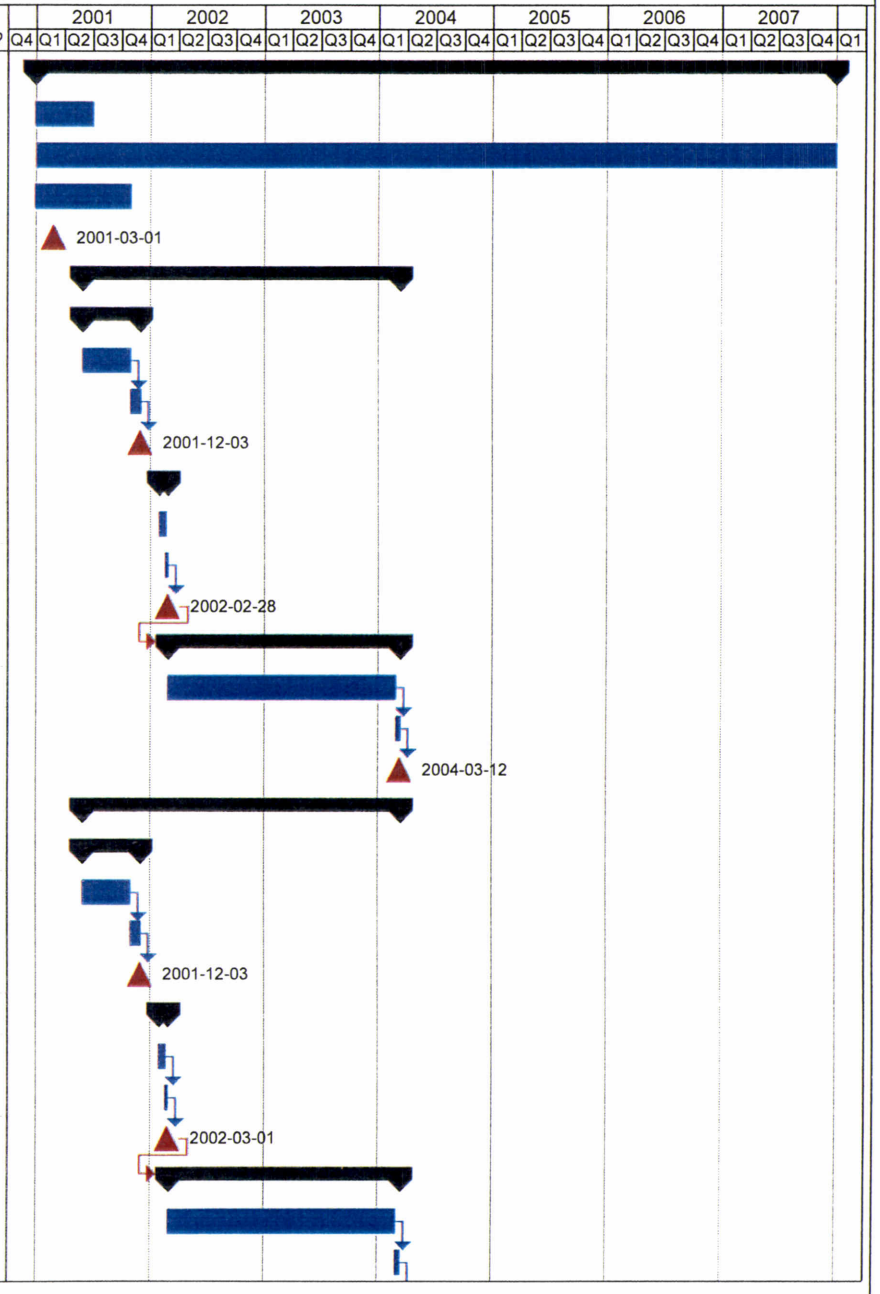
Summary Tasks: underline

Task Milestone Summary

# MMA Construction Tasks

**All Tasks selected**

| WBS (f) | Task | Start | Finish | CostData? |
|---|---|---|---|---|
| 2 | **Site Development** | 2001-01-01 | 2008-01-01 | Yes |
| 2.1 | Review Legalities Regarding Array and OSF Sites | 2001-01-01 | 2001-07-02 | No |
| 2.2 | Maintain Mining claims | 2001-01-04 | 2008-01-01 | Yes |
| 2.3 | Contract A&E Studies | 2001-01-01 | 2001-10-31 | Yes |
| 2.4 | **Hire Construction Manager for Chile** | 2001-03-01 | 2001-03-01 | No |
| 2.5 | **Array Site** | 2001-06-01 | 2004-03-12 | No |
| 2.5.1 | **Prepare Site Development Bid Packages** | 2001-06-01 | 2001-12-03 | No |
| 2.5.1.1 | Prepare Package for Array Site | 2001-06-01 | 2001-11-01 | No |
| 2.5.1.2 | Review Bid Packages | 2001-11-02 | 2001-12-03 | No |
| 2.5.1.3 | **Bid Civil Works Construction** | 2001-12-03 | 2001-12-03 | No |
| 2.5.2 | **Evaluate Array Site Bid Response** | 2002-02-01 | 2002-02-28 | No |
| 2.5.2.1 | Review Bids | 2002-02-01 | 2002-02-21 | No |
| 2.5.2.2 | Recommend Contractors | 2002-02-21 | 2002-02-28 | No |
| 2.5.2.3 | **Award Array Site Contracts** | 2002-02-28 | 2002-02-28 | No |
| 2.5.3 | **Contract Array Site Civil Works** | 2002-03-01 | 2004-03-12 | Yes |
| 2.5.3.1 | Array Site | 2002-03-01 | 2004-02-27 | No |
| 2.5.3.2 | Inspect Completed Site Constr | 2004-03-01 | 2004-03-12 | No |
| 2.5.3.3 | **Accept Site Facility** | 2004-03-12 | 2004-03-12 | No |
| 2.6 | **Operations Support Facility** | 2001-06-01 | 2004-03-15 | No |
| 2.6.1 | **Prepare OSF Bid Packages** | 2001-06-01 | 2001-12-03 | No |
| 2.6.1.1 | Prepare Package for OSF | 2001-06-01 | 2001-11-01 | No |
| 2.6.1.2 | Review Bid Packages | 2001-11-02 | 2001-12-03 | No |
| 2.6.1.3 | **Bid Civil Works Construction** | 2001-12-03 | 2001-12-03 | No |
| 2.6.2 | **Evaluate OSF Bid Response** | 2002-02-01 | 2002-03-01 | No |
| 2.6.2.1 | Review Bids | 2002-02-01 | 2002-02-21 | No |
| 2.6.2.2 | Recommend Contractors | 2002-02-22 | 2002-03-01 | No |
| 2.6.2.3 | **Award Contracts** | 2002-03-01 | 2002-03-01 | No |
| 2.6.3 | **Contract OSF Civil Works** | 2002-03-04 | 2004-03-15 | Yes |
| 2.6.3.1 | Operations Support Facility | 2002-03-04 | 2004-03-01 | No |
| 2.6.3.2 | Inspect Completed OSF Constr | 2004-03-02 | 2004-03-15 | No |

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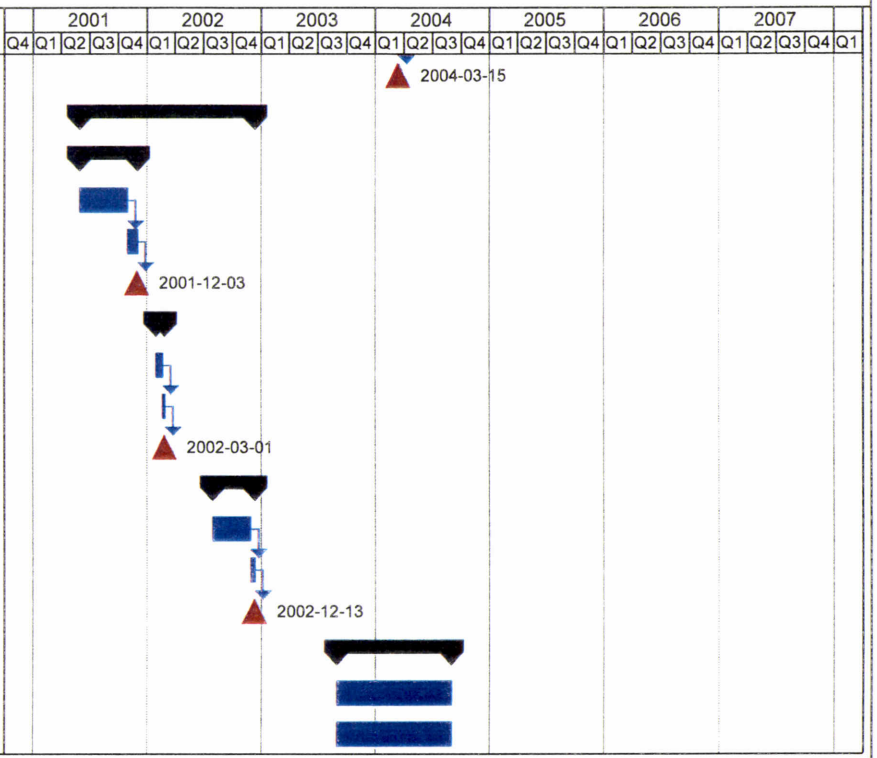
Summary Tasks: **underline**

Task Milestone Summary

# MMA Construction Tasks

**All Tasks selected**

| WBS (f) | Task | Start | Finish | CostData? |
|---|---|---|---|---|
| 2.6.3.3 | **Accept OSF Facility** | 2004-03-15 | 2004-03-15 | No |
| 2.7 | **OSF/Array Link** | 2001-06-01 | 2002-12-13 | No |
| 2.7.1 | **Prepare OSF/Array Link Bid Package** | 2001-06-01 | 2001-12-03 | No |
| 2.7.1.1 | Prepare Package for OSF/Array F/O Link | 2001-06-01 | 2001-11-01 | No |
| 2.7.1.2 | Review Bid Package | 2001-11-02 | 2001-12-03 | No |
| 2.7.1.3 | **Bid OSF/Array Link Construction** | 2001-12-03 | 2001-12-03 | No |
| 2.7.2 | **Evaluate Bid Response** | 2002-02-01 | 2002-03-01 | No |
| 2.7.2.1 | Review Bids | 2002-02-01 | 2002-02-21 | No |
| 2.7.2.2 | Recommend Contractors | 2002-02-22 | 2002-03-01 | No |
| 2.7.2.3 | **Award Contracts** | 2002-03-01 | 2002-03-01 | No |
| 2.7.3 | **Contract Civil Works** | 2002-08-01 | 2002-12-13 | Yes |
| 2.7.3.1 | OSF/Array Link | 2002-08-01 | 2002-11-29 | No |
| 2.7.3.2 | Inspect Completed OSF/Array Link Constr | 2002-12-02 | 2002-12-13 | No |
| 2.7.3.3 | **Accept OSF/Array Link** | 2002-12-13 | 2002-12-13 | No |
| 2.8 | **Prepare for Instrument Assembly** | 2003-09-01 | 2004-08-31 | No |
| 2.8.1 | Equip Array Site | 2003-09-01 | 2004-08-31 | Yes |
| 2.8.2 | Equip Operations Support Facility | 2003-09-01 | 2004-08-31 | Yes |

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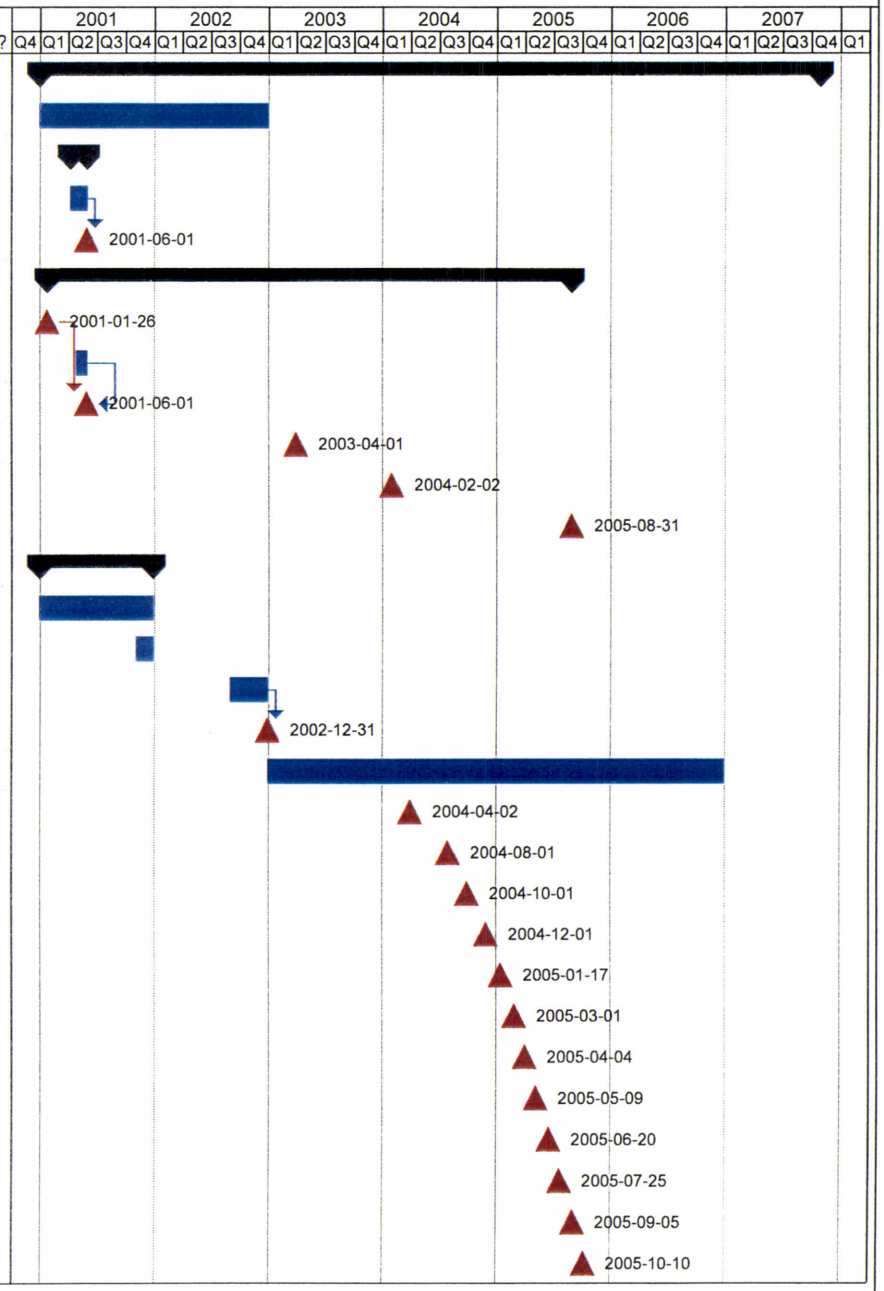
Summary Tasks: **underline**

Task Milestone Summary

# MMA Construction Tasks

**All Tasks selected**

| WBS (f) | Task | Start | Finish | CostData? |
|---|---|---|---|---|
| 3 | **Antenna** | 2001-01-01 | 2007-10-30 | No |
| 3.1 | Antenna Engineering Support | 2001-01-01 | 2002-12-31 | Yes |
| 3.3 | **Procurement of Prototype Antenna** | 2001-04-09 | 2001-06-01 | No |
| 3.3.40 | Acceptance Tests Antenna #1 | 2001-04-09 | 2001-06-01 | No |
| 3.3.45 | **Delivery of Antenna #1** | 2001-06-01 | 2001-06-01 | No |
| 3.8 | **Antenna Transporter** | 2001-01-26 | 2005-08-31 | No |
| 3.8.10 | **Sign Transporter Contract** | 2001-01-26 | 2001-01-26 | Yes |
| 3.8.15 | Transporter Acceptance tests | 2001-04-30 | 2001-06-01 | No |
| 3.8.20 | **Deliver/Accept Transporter #1** | 2001-06-01 | 2001-06-01 | No |
| 3.8.25 | **Contract for Transporters #2, #3** | 2003-04-01 | 2003-04-01 | No |
| 3.8.30 | **Accept Transporter #2 at OSF** | 2004-02-02 | 2004-02-02 | Yes |
| 3.8.35 | **Contract for Transporter #1 Move to site** | 2005-08-31 | 2005-08-31 | Yes |
| 3.15 | **Procurement of Antenna 2** | 2001-01-01 | 2001-12-28 | Yes |
| 3.15.1 | Antenna #2 Contract Supervision | 2001-01-01 | 2001-12-28 | No |
| 3.15.2 | Antenna #2 Acceptance tests | 2001-11-05 | 2001-12-28 | No |
| 3.17 | Negotiate Production Antenna Contract | 2002-09-02 | 2002-12-31 | No |
| 3.20 | **Sign Contract for Production Antennas** | 2002-12-31 | 2002-12-31 | Yes |
| 3.21 | Antenna Contract Supervision | 2003-01-01 | 2006-12-29 | Yes |
| 3.23 | **Accept Antenna #3 at OSF** | 2004-04-02 | 2004-04-02 | Yes |
| 3.25 | **Accept Antenna #4 at OSF** | 2004-08-01 | 2004-08-01 | Yes |
| 3.27 | **Accept Antenna#5 at OSF** | 2004-10-01 | 2004-10-01 | Yes |
| 3.29 | **Accept Antenna#6 at OSF** | 2004-12-01 | 2004-12-01 | Yes |
| 3.31 | **Accept Antenna #7 at OSF** | 2005-01-17 | 2005-01-17 | Yes |
| 3.33 | **Accept Antenna #8 at OSF** | 2005-03-01 | 2005-03-01 | Yes |
| 3.35 | **Accept Antenna #9 at OSF** | 2005-04-04 | 2005-04-04 | Yes |
| 3.37 | **Accept Antenna #10 at OSF** | 2005-05-09 | 2005-05-09 | Yes |
| 3.39 | **Accept Antenna #11 at OSF** | 2005-06-20 | 2005-06-20 | Yes |
| 3.41 | **Accept Antenna #12 at OSF** | 2005-07-25 | 2005-07-25 | Yes |
| 3.43 | **Accept Antenna #13 at OSF** | 2005-09-05 | 2005-09-05 | Yes |
| 3.45 | **Accept Antenna #14 at OSF** | 2005-10-10 | 2005-10-10 | Yes |

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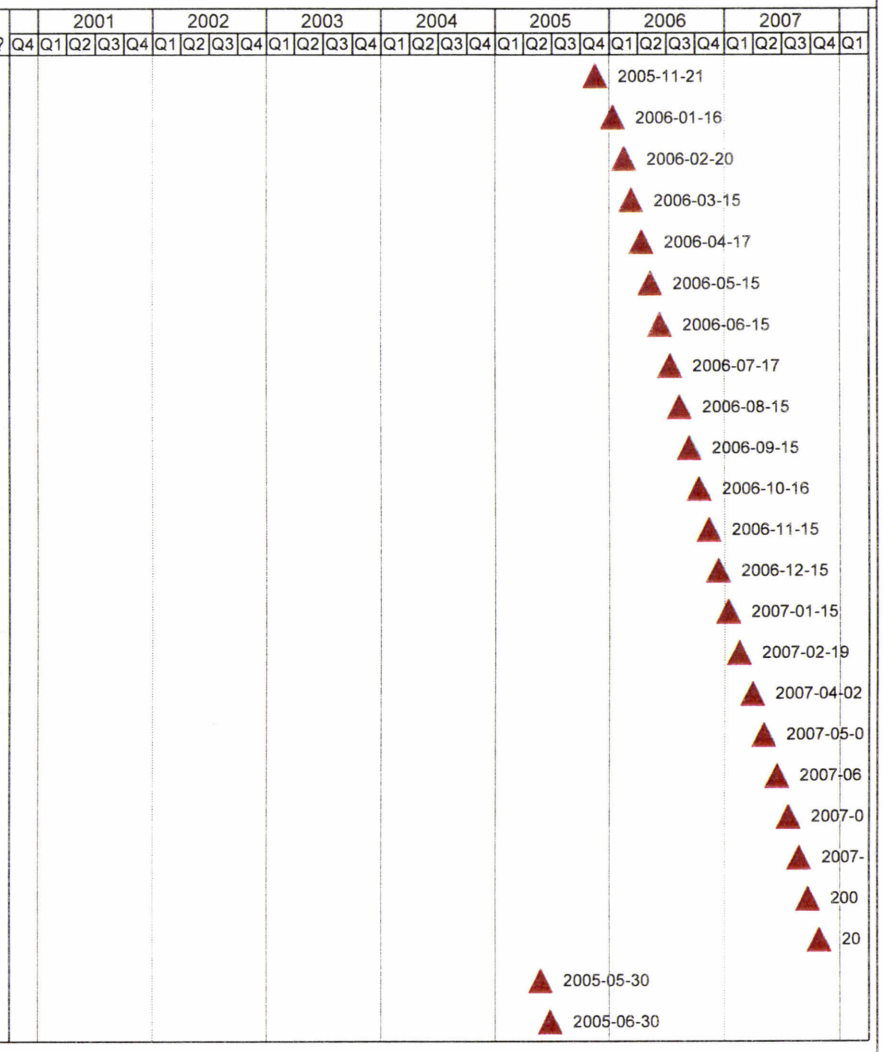
Summary Tasks: underline

Task Milestone Summary

# MMA Construction Tasks

**All Tasks selected**

| WBS (f) | Task | Start | Finish | CostData? |
|---|---|---|---|---|
| 3.47 | **Accept Antenna #15 at OSF** | 2005-11-21 | 2005-11-21 | Yes |
| 3.49 | **Accept Antenna #16 at OSF** | 2006-01-16 | 2006-01-16 | Yes |
| 3.51 | **Accept Antenna #17 at OSF** | 2006-02-20 | 2006-02-20 | Yes |
| 3.53 | **Accept Antenna #18 at OSF** | 2006-03-15 | 2006-03-15 | Yes |
| 3.55 | **Accept Antenna #19 at OSF** | 2006-04-17 | 2006-04-17 | Yes |
| 3.57 | **Accept Antenna #20 at OSF** | 2006-05-15 | 2006-05-15 | Yes |
| 3.59 | **Accept Antenna #21 at OSF** | 2006-06-15 | 2006-06-15 | Yes |
| 3.61 | **Accept Antenna #22 at OSF** | 2006-07-17 | 2006-07-17 | Yes |
| 3.63 | **Accept Antenna #23 at OSF** | 2006-08-15 | 2006-08-15 | Yes |
| 3.65 | **Accept Antenna #24 at OSF** | 2006-09-15 | 2006-09-15 | Yes |
| 3.67 | **Accept Antenna #25 at OSF** | 2006-10-16 | 2006-10-16 | Yes |
| 3.69 | **Accept Antenna #26 at OSF** | 2006-11-15 | 2006-11-15 | Yes |
| 3.71 | **Accept Antenna #27 at OSF** | 2006-12-15 | 2006-12-15 | Yes |
| 3.73 | **Accept Antenna #28 at OSF** | 2007-01-15 | 2007-01-15 | Yes |
| 3.75 | **Accept Antenna #29 at OSF** | 2007-02-19 | 2007-02-19 | Yes |
| 3.77 | **Accept Antenna #30 at OSF** | 2007-04-02 | 2007-04-02 | Yes |
| 3.79 | **Accept Antenna #31 at OSF** | 2007-05-07 | 2007-05-07 | Yes |
| 3.81 | **Accept Antenna #32 at OSF** | 2007-06-18 | 2007-06-18 | Yes |
| 3.83 | **Accept Antenna #33 at OSF** | 2007-07-23 | 2007-07-23 | Yes |
| 3.85 | **Accept Antenna #34 at OSF** | 2007-08-27 | 2007-08-27 | Yes |
| 3.87 | **Accept Antenna #35 at OSF** | 2007-09-24 | 2007-09-24 | Yes |
| 3.89 | **Accept Antenna #36 at OSF** | 2007-10-30 | 2007-10-30 | Yes |
| 3.91 | **Accept Antenna #1 at OSF** | 2005-05-30 | 2005-05-30 | No |
| 3.93 | **Accept Antenna #2 at OSF** | 2005-06-30 | 2005-06-30 | No |



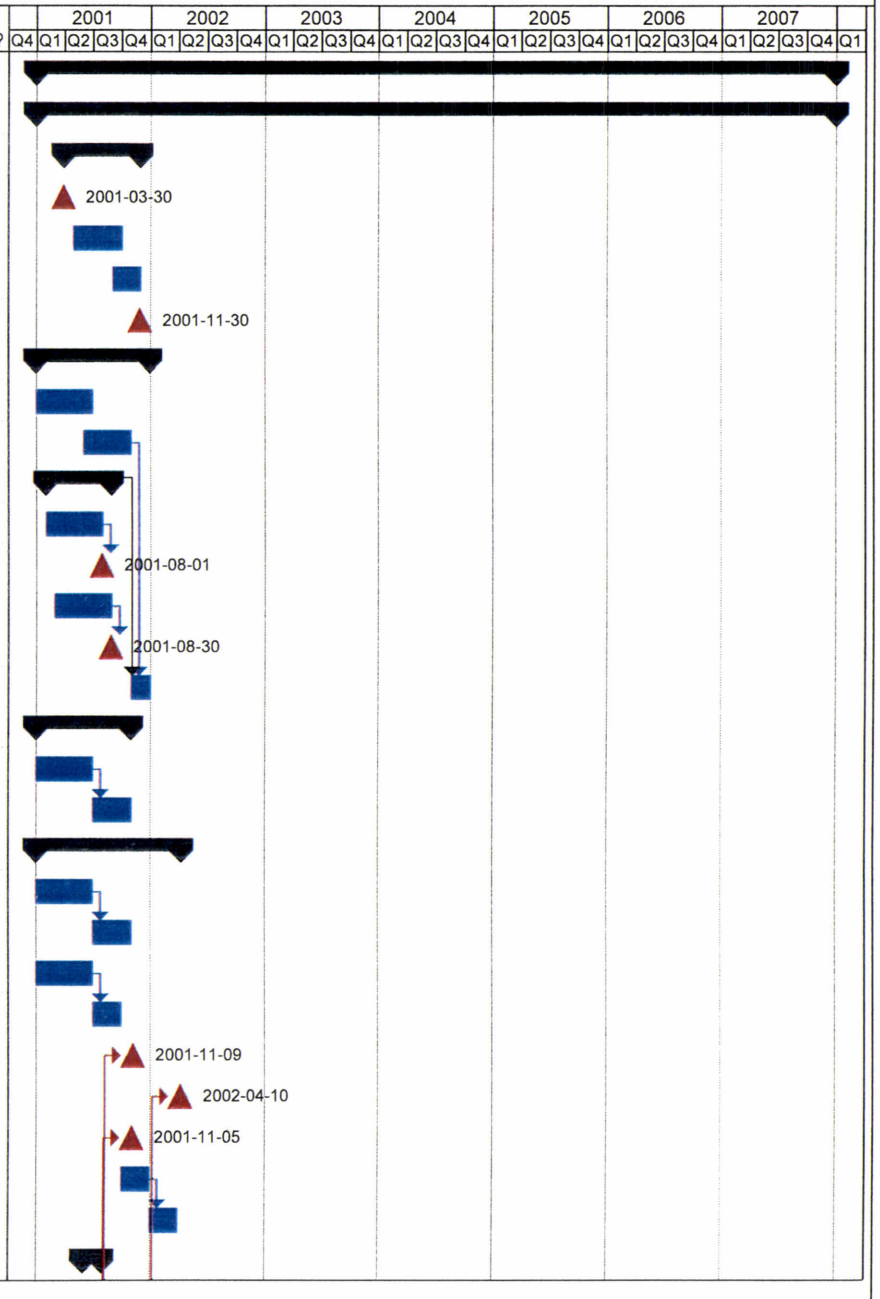

Milestones: **bold type**
Summary Tasks: **underline**

Task Milestone Summary

# MMA Construction Tasks

**All Tasks selected**

| WBS (f) | Task | Start | Finish | CostData? |
|---|---|---|---|---|
| 4. | **Receivers** | 2001-01-01 | 2008-01-01 | No |
| 4.1 | **Prototype Production Receiver ( PPR )** | 2001-01-01 | 2008-01-01 | No |
| 4.1.1 | **Prototype Production Receiver Cryogenics ( PPRC )** | 2001-03-30 | 2001-11-30 | No |
| 4.1.1.1 | **CDR PPRC** | 2001-03-30 | 2001-03-30 | No |
| 4.1.1.2 | Fabricate PPRC | 2001-04-30 | 2001-10-01 | Yes |
| 4.1.1.3 | Test PPRC | 2001-09-03 | 2001-11-30 | Yes |
| 4.1.1.4 | **Deliver PPRC** | 2001-11-30 | 2001-11-30 | No |
| 4.1.2 | **PPR Dewar** | 2001-01-01 | 2001-12-31 | No |
| 4.1.2.1 | PPR Dewar Design | 2001-01-01 | 2001-06-29 | Yes |
| 4.1.2.2 | PPR Dewar Fabrication and Vacuum Testing | 2001-06-01 | 2001-10-30 | Yes |
| 4.1.2.3 | **PPR Vacuum Windows and IR Filters** | 2001-02-01 | 2001-08-30 | Yes |
| 4.1.2.3.1 | PPR Vacuum Windows fabrication | 2001-02-01 | 2001-07-31 | No |
| 4.1.2.3.2 | **Acceptance PPR Vacuum Windows** | 2001-08-01 | 2001-08-01 | No |
| 4.1.2.3.3 | PPR IR Filter fabrication | 2001-03-01 | 2001-08-29 | No |
| 4.1.2.3.4 | **Acceptance PPR IR Windows** | 2001-08-30 | 2001-08-30 | No |
| 4.1.2.4 | PPR Cryogenics/Dewar Assembly and Testing | 2001-11-01 | 2001-12-31 | Yes |
| 4.1.3 | **PPR Electronics** | 2001-01-01 | 2001-10-31 | No |
| 4.1.3.1 | PPR Control-Monitoring and Bias Electronics Design | 2001-01-01 | 2001-06-29 | Yes |
| 4.1.3.2 | PPR Control-Monitor and Bias Electronics Construction | 2001-07-02 | 2001-10-31 | Yes |
| 4.1.4 | **PPR Receiver Inserts** | 2001-01-01 | 2002-04-10 | No |
| 4.1.4.1 | Insert Mechanical-Thermal Design, Bands <275 GHz (Wavegu | 2001-01-01 | 2001-06-29 | Yes |
| 4.1.4.2 | Insert Component Fabrication for Bands <275 GHz | 2001-07-02 | 2001-10-31 | Yes |
| 4.1.4.3 | Insert Mechanical-Thermal Design for Bands >275 GHz (Quasi | 2001-01-01 | 2001-06-29 | Yes |
| 4.1.4.4 | Insert Component Fabrication for Bands >275 Ghz | 2001-07-02 | 2001-09-28 | Yes |
| 4.1.4.5 | **Accept 211-275 GHz Detector Modules for PPR** | 2001-11-09 | 2001-11-09 | No |
| 4.1.4.6 | **Accept 602-720 GHz Detector Modules for PPR** | 2002-04-10 | 2002-04-10 | No |
| 4.1.4.7 | **Accept IF Amplifiers for PPR** | 2001-11-05 | 2001-11-05 | No |
| 4.1.4.8 | PPR Insert Assembly (3 Bands) | 2001-10-01 | 2001-12-28 | Yes |
| 4.1.4.9 | PPR Insert Testing (3 Bands) | 2001-12-31 | 2002-03-29 | Yes |
| 4.1.5 | **PPR Vacuum System** | 2001-06-01 | 2001-07-31 | No |



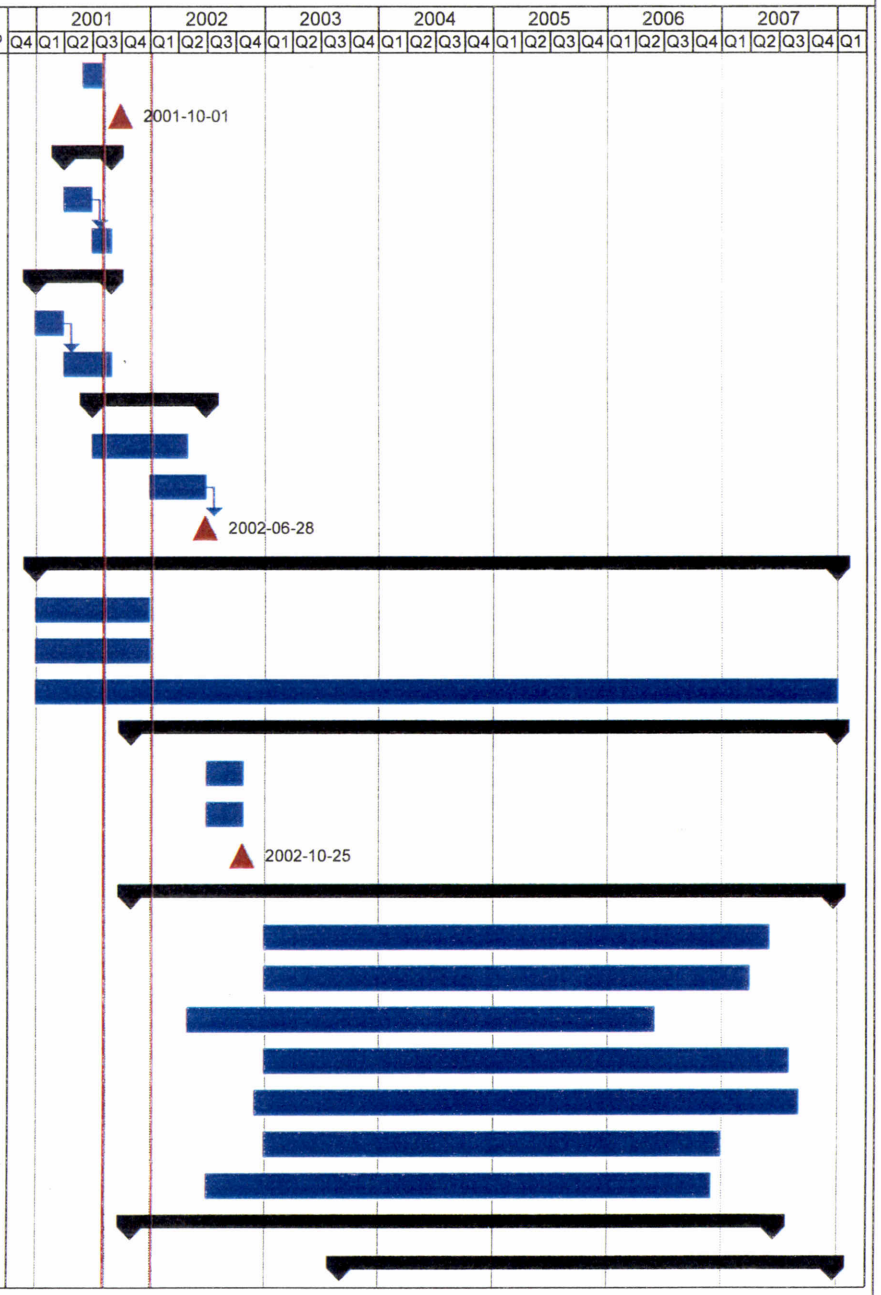

Milestones: **bold type**
Summary Tasks: **underline**

Task Milestone Summary

# MMA Construction Tasks

**All Tasks selected**

| WBS (f) | Task | Start | Finish | CostData? |
|---|---|---|---|---|
| 4.1.5.1 | PPR Vacuum System Assembly | 2001-06-01 | 2001-07-31 | Yes |
| **4.1.6** | **Accept PPR LO System** | **2001-10-01** | **2001-10-01** | **No** |
| **4.1.7** | **PPR Post IF System** | **2001-04-02** | **2001-08-30** | **No** |
| 4.1.7.1 | PPR Post IF System Design | 2001-04-02 | 2001-06-29 | Yes |
| 4.1.7.2 | PPR Post IF System Construction and Testing | 2001-07-02 | 2001-08-30 | Yes |
| **4.1.8** | **Prototype Production Receiver Frame** | **2001-01-01** | **2001-08-30** | **No** |
| 4.1.8.1 | PPR Frame Design | 2001-01-01 | 2001-03-30 | Yes |
| 4.1.8.2 | PPR Frame Fabrication | 2001-04-02 | 2001-08-30 | Yes |
| **4.1.9** | **PPR Assembly and Test** | **2001-07-02** | **2002-06-28** | **No** |
| 4.1.9.1 | Prototype Production Receiver Integration | 2001-07-02 | 2002-04-30 | Yes |
| 4.1.9.2 | PPR Testing and Evaluation | 2001-12-31 | 2002-06-28 | Yes |
| **4.1.9.3** | **Complete Prototype Production Receiver** | **2002-06-28** | **2002-06-28** | **No** |
| **4.1.10** | **PPR Test Equipment and Test Sets** | **2001-01-01** | **2008-01-01** | **No** |
| 4.1.10.1 | Design and build Prototype and Production Receiver Test Set | 2001-01-01 | 2001-12-28 | Yes |
| 4.1.10.2 | Design and Fabricate Receiver Insert Test Set | 2001-01-01 | 2001-12-31 | Yes |
| 4.1.10.3 | General Test Equipment | 2001-01-01 | 2008-01-01 | Yes |
| **4.2** | **Production MMA Receiver (MMA Rx)** | **2001-11-01** | **2007-12-31** | **No** |
| 4.2.1 | MMA Receiver (MMA Rx) Design Refinement | 2002-07-01 | 2002-10-25 | Yes |
| 4.2.2 | MMA Receiver (MMA Rx) Documentation | 2002-07-01 | 2002-10-25 | Yes |
| **4.2.3** | **Release MMA Receiver (MMA Rx) for Manufacture** | **2002-10-25** | **2002-10-25** | **No** |
| **4.2.4** | **Production of MMA Rx Subassemblies** | **2001-11-01** | **2007-12-21** | **No** |
| 4.2.4.1 | MMA Rx Dewar Fabrication | 2003-01-01 | 2007-05-31 | Yes |
| 4.2.4.2 | MMA Rx Cryogenics Fabrication | 2003-01-01 | 2007-03-30 | Yes |
| 4.2.4.3 | Vacuum Windows and IR Filters Fabrication | 2002-05-01 | 2006-05-31 | Yes |
| 4.2.4.4 | Receiver Insert Fabrication | 2003-01-01 | 2007-07-31 | Yes |
| 4.2.4.5 | MMA Receiver Frame Fabrication and assembly | 2002-12-02 | 2007-08-31 | Yes |
| 4.2.4.6 | Vacuum System Fabrication and testing. | 2003-01-01 | 2006-12-29 | Yes |
| 4.2.4.7 | Bias and Control-Monitoring Electronics Construction | 2002-07-01 | 2006-11-28 | Yes |
| **4.2.4.8** | **Accept Detector Modules** | **2001-11-01** | **2007-06-14** | **No** |
| **4.2.4.9** | **Assemble Receiver Inserts and Test** | **2003-09-02** | **2007-12-21** | **Yes** |



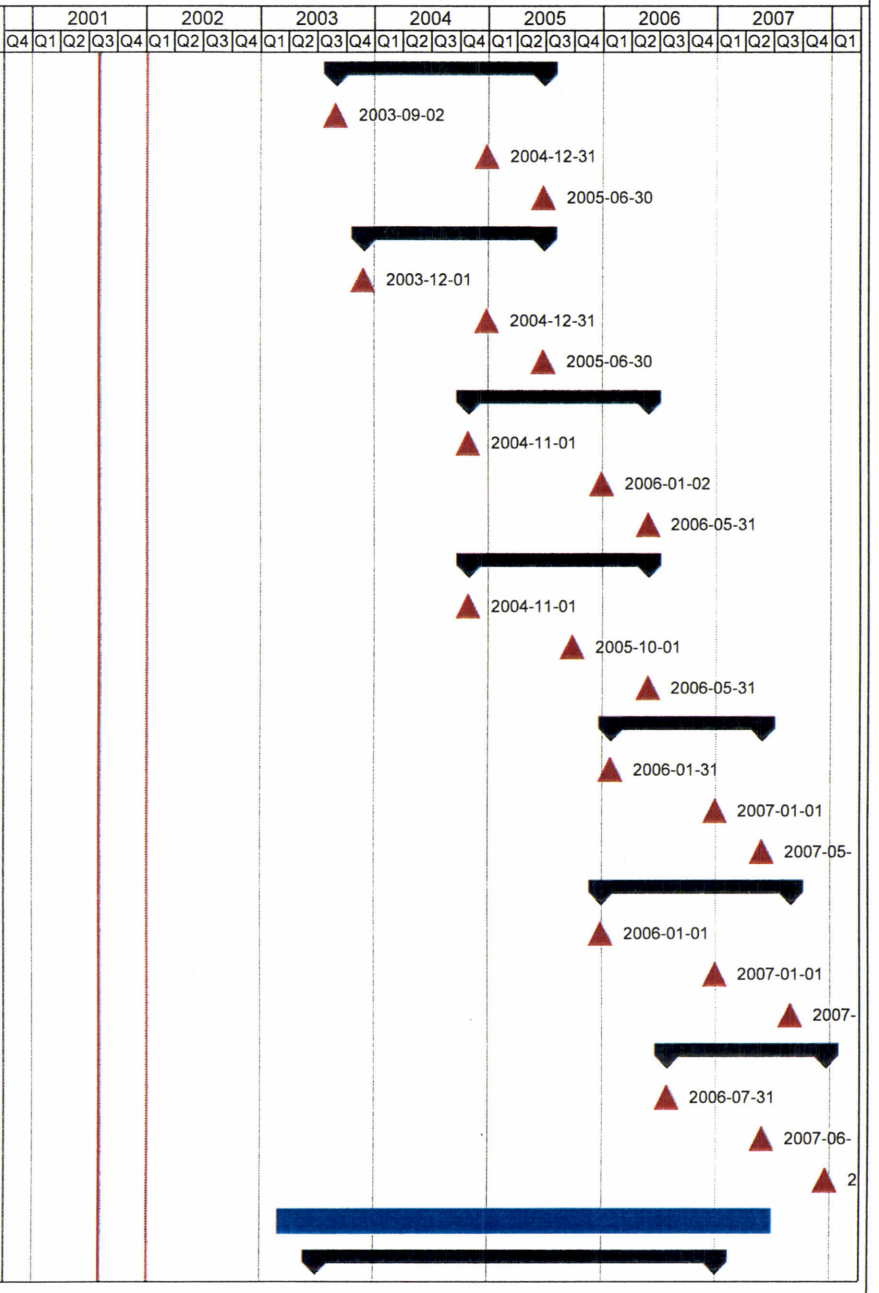

Milestones: **bold type**
Summary Tasks: **underline**

Task Milestone Summary

# MMA Construction Tasks

**All Tasks selected**

| WBS (f) | Task | Start | Finish | CostData? |
|---|---|---|---|---|
| 4.2.4.9.1 | **Deliver 211-275 GHz Receiver Inserts** | 2003-09-02 | 2005-06-30 | No |
| 4.2.4.9.1.1 | Deliver 211-275 GHz Receiver Inserts #1-7 | 2003-09-02 | 2003-09-02 | No |
| 4.2.4.9.1.2 | Deliver 211-275 GHz Receiver Inserts #8-26 | 2004-12-31 | 2004-12-31 | No |
| 4.2.4.9.1.3 | Deliver 211-275 GHz Receiver Inserts #27-40 | 2005-06-30 | 2005-06-30 | No |
| 4.2.4.9.2 | **Deliver 602-720 GHz Receiver Inserts** | 2003-12-01 | 2005-06-30 | No |
| 4.2.4.9.2.1 | Deliver 602-720 GHz Receiver Inserts #1-7 | 2003-12-01 | 2003-12-01 | No |
| 4.2.4.9.2.2 | Deliver 602-720 GHz Receiver Inserts #8-26 | 2004-12-31 | 2004-12-31 | No |
| 4.2.4.9.2.3 | Deliver 602-720 GHz Receiver Inserts #27-40 | 2005-06-30 | 2005-06-30 | No |
| 4.2.4.9.3 | **Deliver 275-370 GHz Receiver Inserts** | 2004-11-01 | 2006-05-31 | No |
| 4.2.4.9.3.1 | Deliver 275-370 GHz Receiver Inserts #1-5 | 2004-11-01 | 2004-11-01 | No |
| 4.2.4.9.3.2 | Deliver 275-370 GHz Receiver Inserts #6-30 | 2006-01-02 | 2006-01-02 | No |
| 4.2.4.9.3.3 | Deliver 275-370 GHz Receiver Inserts #30-40 | 2006-05-31 | 2006-05-31 | No |
| 4.2.4.9.4 | **Deliver 89-116 GHz Receiver Inserts** | 2004-11-01 | 2006-05-31 | No |
| 4.2.4.9.4.1 | Deliver 89-116 GHz Receiver Inserts #1-5 | 2004-11-01 | 2004-11-01 | No |
| 4.2.4.9.4.2 | Deliver 89-116 GHz Receiver Inserts #6-30 | 2005-10-01 | 2005-10-01 | No |
| 4.2.4.9.4.3 | Deliver 89-116 GHz Receiver Inserts # 31-40 | 2006-05-31 | 2006-05-31 | No |
| 4.2.4.9.5 | **Deliver 163-211 GHz Receiver Inserts** | 2006-01-31 | 2007-05-31 | No |
| 4.2.4.9.5.1 | Deliver 163-211 GHz Receiver Inserts #1-5 | 2006-01-31 | 2006-01-31 | No |
| 4.2.4.9.5.2 | Deliver 163-211 GHz Receiver Inserts #6-30 | 2007-01-01 | 2007-01-01 | No |
| 4.2.4.9.5.3 | Deliver 163-211 GHz Receiver Inserts #31-40 | 2007-05-31 | 2007-05-31 | No |
| 4.2.4.9.6 | **Deliver 385-500 GHz Receiver Inserts** | 2006-01-01 | 2007-08-31 | No |
| 4.2.4.9.6.1 | Deliver 385-500 GHz Receiver Inserts #1-5 | 2006-01-01 | 2006-01-01 | No |
| 4.2.4.9.6.2 | Deliver 385-500 GHz Receiver Inserts #6-30 | 2007-01-01 | 2007-01-01 | No |
| 4.2.4.9.6.3 | Deliver 385-500 GHz Receiver Inserts #31-40 | 2007-08-31 | 2007-08-31 | No |
| 4.2.4.9.7 | **Deliver 125-163 GHz Receiver Inserts** | 2006-07-31 | 2007-12-21 | No |
| 4.2.4.9.7.1 | Deliver 125-163 GHz Modules #1-5 | 2006-07-31 | 2006-07-31 | No |
| 4.2.4.9.7.2 | Deliver 125-163 GHz Modules #6-30 | 2007-06-01 | 2007-06-01 | No |
| 4.2.4.9.7.3 | Deliver 125-163 GHz Modules #31-40 | 2007-12-21 | 2007-12-21 | No |
| 4.2.4.10 | Assemble MMA Rx IF System | 2003-03-03 | 2007-06-29 | Yes |
| 4.2.5 | **Accept MMA Rx Subassemblies** | 2003-06-30 | 2007-01-02 | No |



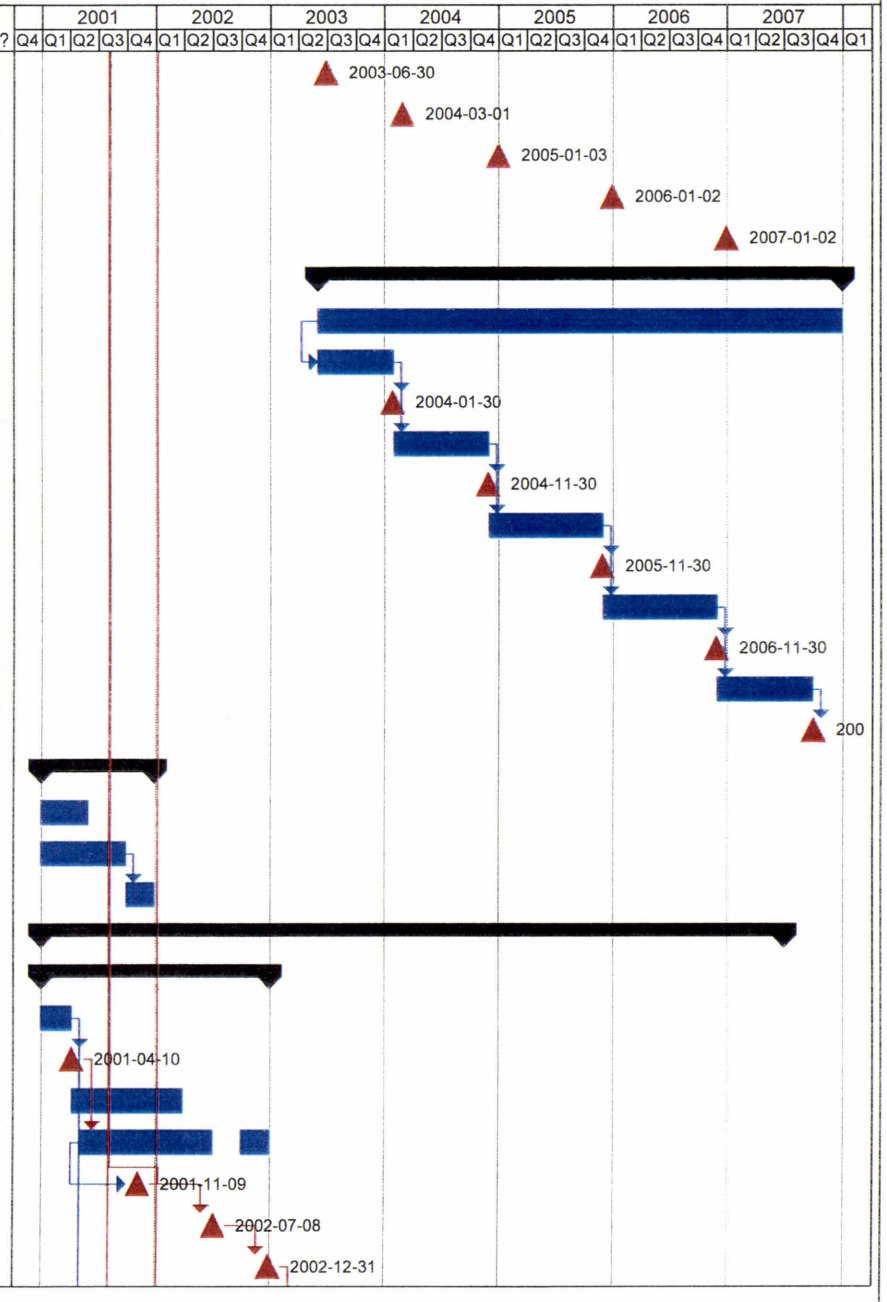

Milestones: **bold type**
Summary Tasks: **underline**

Task ▬ Milestone ▲ Summary ▬

# MMA Construction Tasks

**All Tasks selected**

| WBS (f) | Task | Start | Finish | CostData? |
|---|---|---|---|---|
| 4.2.5.1 | **Accept MMA Receiver Subassemblies 1 to 6** | 2003-06-30 | 2003-06-30 | No |
| 4.2.5.2 | **Accept MMA Receiver Subassemblies 7 to 16** | 2004-03-01 | 2004-03-01 | No |
| 4.2.5.3 | **Accept MMA Receiver Subassemblies 17 to 26** | 2005-01-03 | 2005-01-03 | No |
| 4.2.5.4 | **Accept MMA Receiver Subassemblies 27 to 36** | 2006-01-02 | 2006-01-02 | No |
| 4.2.5.5 | **Accept MMA Receiver Subassemblies 37 to 40** | 2007-01-02 | 2007-01-02 | No |
| 4.2.6 | **Assemble MMA Receivers** | 2003-06-03 | 2007-12-31 | No |
| 4.2.6.1 | Integrate Test & Commission MMA Receivers | 2003-06-03 | 2007-12-31 | Yes |
| 4.2.6.2 | MMA Receivers 1 to 6 | 2003-06-03 | 2004-01-30 | No |
| 4.2.6.3 | **Deliver MMA Receiver #1-6** | 2004-01-30 | 2004-01-30 | No |
| 4.2.6.4 | MMA Receivers 7 to 16 | 2004-02-02 | 2004-11-30 | No |
| 4.2.6.5 | **Deliver MMA Receiver #7-16** | 2004-11-30 | 2004-11-30 | No |
| 4.2.6.6 | MMA Receivers 17 to 26 | 2004-12-01 | 2005-11-30 | No |
| 4.2.6.7 | **Deliver MMA Receiver #17-26** | 2005-11-30 | 2005-11-30 | No |
| 4.2.6.8 | MMA Receivers 27 to 36 | 2005-12-01 | 2006-11-30 | No |
| 4.2.6.9 | **Deliver MMA Receiver #27-36** | 2006-11-30 | 2006-11-30 | No |
| 4.2.6.10 | MMA Receivers 37 to 40 | 2006-12-01 | 2007-09-28 | No |
| 4.2.6.11 | **Deliver MMA Receiver #37-40** | 2007-10-01 | 2007-10-01 | No |
| 4.5 | **Evaluation Receiver #2** | 2001-01-01 | 2001-12-28 | No |
| 4.5.1 | Construct and test Cryo system for 2nd Evaluation Receiver | 2001-01-01 | 2001-05-31 | Yes |
| 4.5.2 | Fabrication and assembly of 2nd Evaluation Receiver. | 2001-01-01 | 2001-09-28 | Yes |
| 4.5.3 | Test and Commission 2nd Evaluation Receiver | 2001-10-01 | 2001-12-28 | Yes |
| 4.3 | **SIS Detector Modules** | 2001-01-01 | 2007-07-02 | No |
| 4.3.1 | **211-275 GHz Detector Modules** | 2001-01-01 | 2002-12-31 | No |
| 4.3.1.1 | Design, Fab, and Test 211-275 GHz Mixer Design | 2001-01-01 | 2001-04-09 | Yes |
| 4.3.1.2 | **Deliver Production Design 211-275 GHz SIS Mixer** | 2001-04-10 | 2001-04-10 | No |
| 4.3.1.3 | Fabricate 211-275 GHz mixer blocks | 2001-04-10 | 2002-03-29 | Yes |
| 4.3.1.4 | Fabricate & test 211-275 GHz SIS Mixer Detector Modules | 2001-05-04 | 2002-12-31 | Yes |
| 4.3.1.5 | **Deliver 211-275 GHz SIS mixer Detector Module #1-14** | 2001-11-09 | 2001-11-09 | No |
| 4.3.1.6 | **Deliver 211-275 GHz SIS mixer Detector Module #15-52** | 2002-07-08 | 2002-07-08 | No |
| 4.3.1.7 | **Deliver 211-275 GHz SIS mixer Detector Module #53-80** | 2002-12-31 | 2002-12-31 | No |



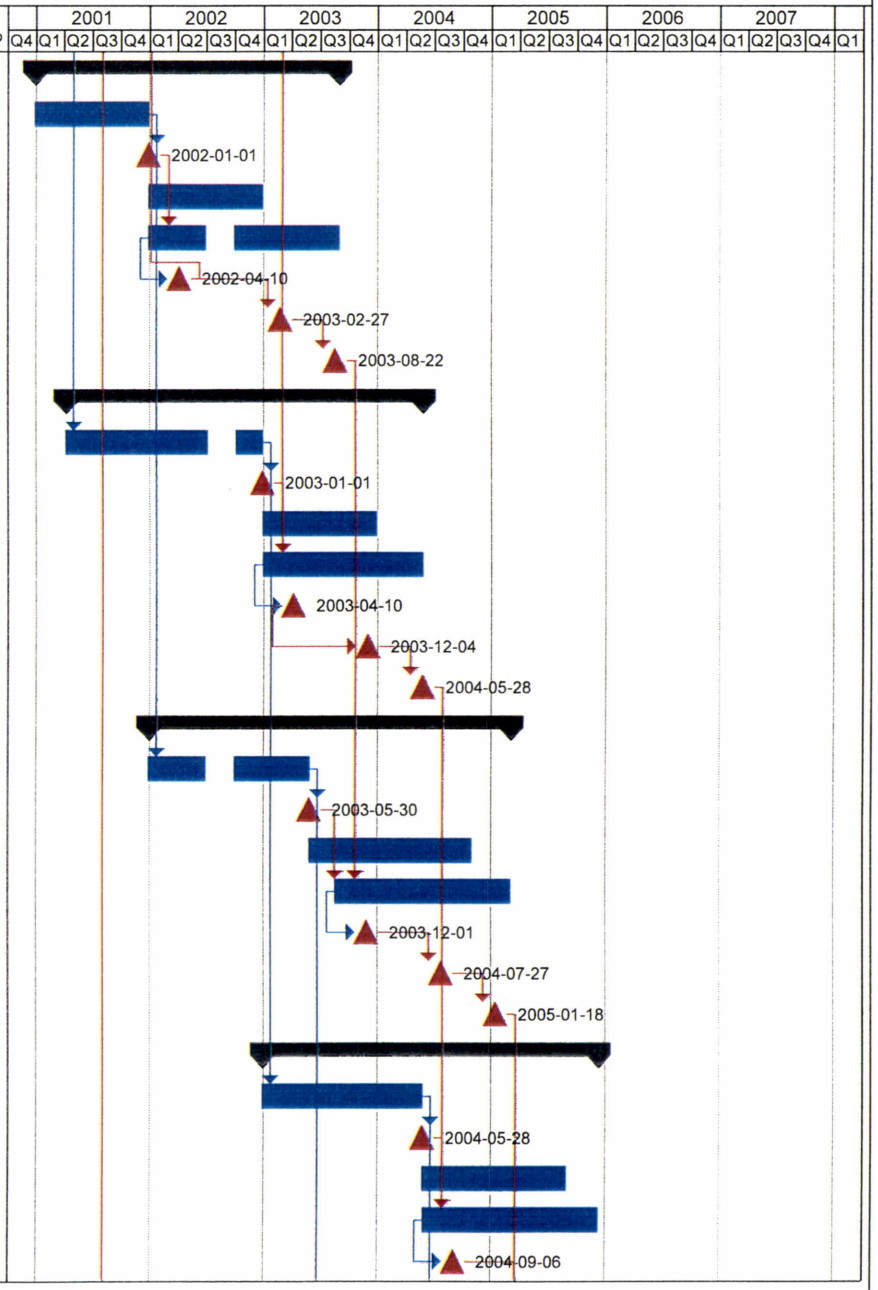

Milestones: **bold type**
Summary Tasks: underline

Task Milestone Summary

# MMA Construction Tasks

**All Tasks selected**

| WBS (f) | Task | Start | Finish | CostData? |
|---|---|---|---|---|
| 4.3.2 | **602-720 GHz Detector Modules** | 2001-01-01 | 2003-09-01 | No |
| 4.3.2.1 | Design, Fab, and Test 602-720 GHz Mixer Design | 2001-01-01 | 2002-01-01 | Yes |
| 4.3.2.2 | **Deliver Production Design 602-720 GHz SIS Mixer** | 2002-01-01 | 2002-01-01 | No |
| 4.3.2.3 | Fabricate 602-720 GHz mixer blocks | 2002-01-01 | 2002-12-31 | Yes |
| 4.3.2.4 | Fabricate & test 602-720 GHz SIS Mixer Detector Modules | 2002-01-02 | 2003-09-01 | Yes |
| 4.3.2.5 | **Deliver 602-720 GHz SIS mixer Detector Module #1-14** | 2002-04-10 | 2002-04-10 | No |
| 4.3.2.6 | **Deliver 602-720 GHz SIS mixer Detector Module #15-52** | 2003-02-27 | 2003-02-27 | No |
| 4.3.2.7 | **Deliver 602-720 GHz SIS mixer Detector Module #53-80** | 2003-08-22 | 2003-08-22 | No |
| 4.3.3 | **275-370 GHz Detector Modules** | 2001-04-10 | 2004-05-28 | No |
| 4.3.3.1 | Design, Fab, and Test 275-370 GHz Mixer Design | 2001-04-10 | 2003-01-01 | Yes |
| 4.3.3.2 | **Deliver Production Design 275-370 GHz SIS Mixer** | 2003-01-01 | 2003-01-01 | No |
| 4.3.3.3 | Fabricate 275-370 GHz mixer blocks | 2003-01-01 | 2003-12-31 | Yes |
| 4.3.3.4 | Fabricate & test 275-370 GHz SIS Mixer Detector Modules | 2003-01-02 | 2004-05-28 | Yes |
| 4.3.3.5 | **Deliver 275-370 GHz SIS mixer Detector Module #1-14** | 2003-04-10 | 2003-04-10 | No |
| 4.3.3.6 | **Deliver 275-370 GHz SIS mixer Detector Module #15-52** | 2003-12-04 | 2003-12-04 | No |
| 4.3.3.7 | **Deliver 275-370 GHz SIS mixer Detector Module #53-80** | 2004-05-28 | 2004-05-28 | No |
| 4.3.4 | **89-116 GHz Detector Modules** | 2002-01-02 | 2005-03-07 | No |
| 4.3.4.1 | Design, Fab, and Test 89-116 GHz Mixer Design | 2002-01-02 | 2003-05-30 | Yes |
| 4.3.4.2 | **Deliver Production Design 89-116 GHz SIS Mixer** | 2003-05-30 | 2003-05-30 | No |
| 4.3.4.3 | Fabricate 89-116 GHz mixer blocks | 2003-05-30 | 2004-11-01 | Yes |
| 4.3.4.4 | Fabricate 89-116 GHz SIS mixer Detector Modules | 2003-08-22 | 2005-03-07 | Yes |
| 4.3.4.5 | **Deliver 89-116 GHz SIS mixer Detector Module #1-14** | 2003-12-01 | 2003-12-01 | No |
| 4.3.4.6 | **Deliver 89-116 GHz SIS mixer Detector Module #15-52** | 2004-07-27 | 2004-07-27 | No |
| 4.3.4.7 | **Deliver 89-116 GHz SIS mixer Detector Module #53-80** | 2005-01-18 | 2005-01-18 | No |
| 4.3.5 | **163-211 GHz Detector Modules** | 2003-01-01 | 2005-12-13 | No |
| 4.3.5.1 | Design, Fab, and Test 163-211 GHz Mixer Design | 2003-01-01 | 2004-05-28 | Yes |
| 4.3.5.2 | **Deliver Production Design 163-211 GHz SIS Mixer** | 2004-05-28 | 2004-05-28 | No |
| 4.3.5.3 | Fabricate 163-211 GHz Mixer Blocks | 2004-05-28 | 2005-09-01 | Yes |
| 4.3.5.4 | Fabricate & test 163-211 GHz SIS Mixer Detector Modules | 2004-05-31 | 2005-12-13 | Yes |
| 4.3.5.5 | **Deliver 163-211 GHz SIS mixer Detector Module #1-14** | 2004-09-06 | 2004-09-06 | No |

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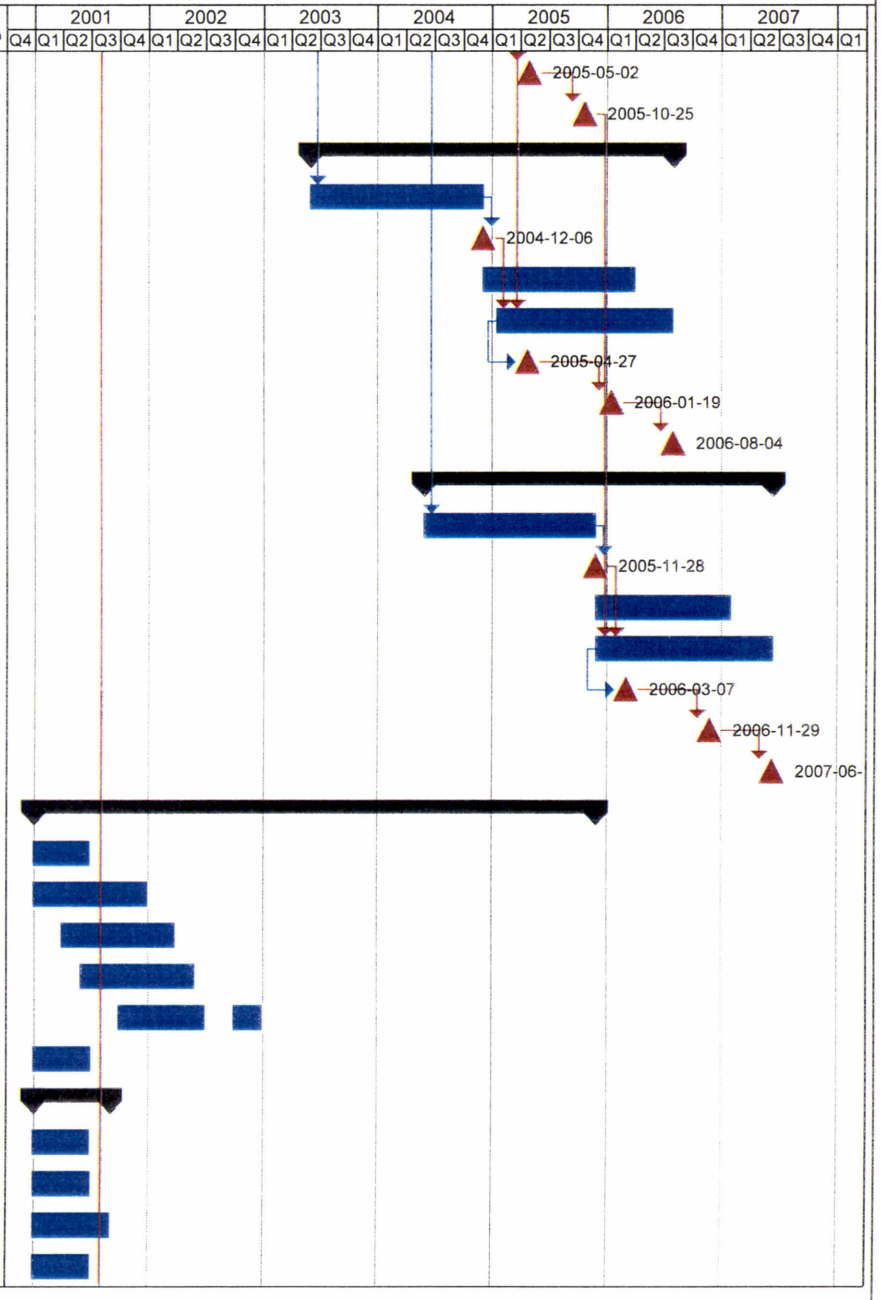
Summary Tasks: underline

Task Milestone Summary

# MMA Construction Tasks

**All Tasks selected**

| WBS (f) | Task | Start | Finish | CostData? |
|---|---|---|---|---|
| 4.3.5.6 | **Deliver 163-211 GHz SIS mixer Detector Module #15-52** | 2005-05-02 | 2005-05-02 | No |
| 4.3.5.7 | **Deliver 163-211 GHz SIS mixer Detector Module #53-80** | 2005-10-25 | 2005-10-25 | No |
| 4.3.6 | **385-500 GHz Detector Modules** | 2003-06-02 | 2006-08-04 | No |
| 4.3.6.1 | Design, Fab, and Test 385-500 GHz Mixer Design | 2003-06-02 | 2004-12-06 | Yes |
| 4.3.6.2 | **Deliver Production Design 385-500 GHz SIS Mixer** | 2004-12-06 | 2004-12-06 | No |
| 4.3.6.3 | Fabricate 385-500 GHz mixer blocks | 2004-12-06 | 2006-04-03 | Yes |
| 4.3.6.4 | Fabricate & Test 385-500 GHz SIS Mixer Detector Modules | 2005-01-18 | 2006-08-03 | Yes |
| 4.3.6.5 | **Deliver 385-500 GHz SIS mixer Detector Module #1-14** | 2005-04-27 | 2005-04-27 | No |
| 4.3.6.6 | **Deliver 385-500 GHz SIS mixer Detector Module #15-52** | 2006-01-19 | 2006-01-19 | No |
| 4.3.6.7 | **Deliver 385-500 GHz SIS mixer Detector Module #53-80** | 2006-08-04 | 2006-08-04 | No |
| 4.3.7 | **125-163 GHz Detector Modules** | 2004-05-31 | 2007-06-14 | No |
| 4.3.7.1 | Design, Fab, and Test 125-163 GHz Mixer Design | 2004-05-31 | 2005-11-28 | Yes |
| 4.3.7.2 | **Deliver Production Design 125-163 GHz SIS Mixer** | 2005-11-28 | 2005-11-28 | No |
| 4.3.7.3 | Fabricate 125-163 GHz mixer blocks | 2005-11-28 | 2007-02-01 | Yes |
| 4.3.7.4 | Fabricate & Test 125-163 GHz SIS Mixer Detector Modules | 2005-11-29 | 2007-06-14 | Yes |
| 4.3.7.5 | **Deliver 125-163 GHz SIS mixer Detector Module #1-14** | 2006-03-07 | 2006-03-07 | No |
| 4.3.7.6 | **Deliver 125-163 GHz SIS mixer Detector Module #15-52** | 2006-11-29 | 2006-11-29 | No |
| 4.3.7.7 | **Deliver 125-163 GHz SIS mixer Detector Module #53-80** | 2007-06-14 | 2007-06-14 | No |
| 4.3.8 | **SIS Detector Module Fabrication & Test Facilities** | 2001-01-01 | 2005-11-29 | No |
| 4.3.8.1 | Build SIS Fabrication Equipment | 2001-01-02 | 2001-06-29 | Yes |
| 4.3.8.2 | Build SIS Test Dewar & Rack #1 | 2001-01-02 | 2001-12-31 | Yes |
| 4.3.8.3 | Build SIS Test Dewar & Rack #2 | 2001-04-02 | 2002-03-29 | Yes |
| 4.3.8.4 | Build SIS Test Dewar & Rack #3 | 2001-06-01 | 2002-05-30 | Yes |
| 4.3.8.5 | Build SIS Test Dewar & Rack #4 | 2001-10-01 | 2002-12-30 | Yes |
| 4.3.8.6 | Build Wafer Evaluation Test Sets | 2001-01-02 | 2001-07-02 | Yes |
| 4.3.8.7 | **Test Equipment** | 2001-01-01 | 2001-09-03 | No |
| 4.3.8.7.1 | General SIS Test Equipment | 2001-01-01 | 2001-06-29 | Yes |
| 4.3.8.7.2 | Equip Network Analyzer to 330 GHz | 2001-01-02 | 2001-07-02 | Yes |
| 4.3.8.7.3 | Near-Field Antenna Test Equipment | 2001-01-02 | 2001-09-03 | Yes |
| 4.3.8.8 | Build 211-275 GHz Test Plates | 2001-01-02 | 2001-07-02 | Yes |



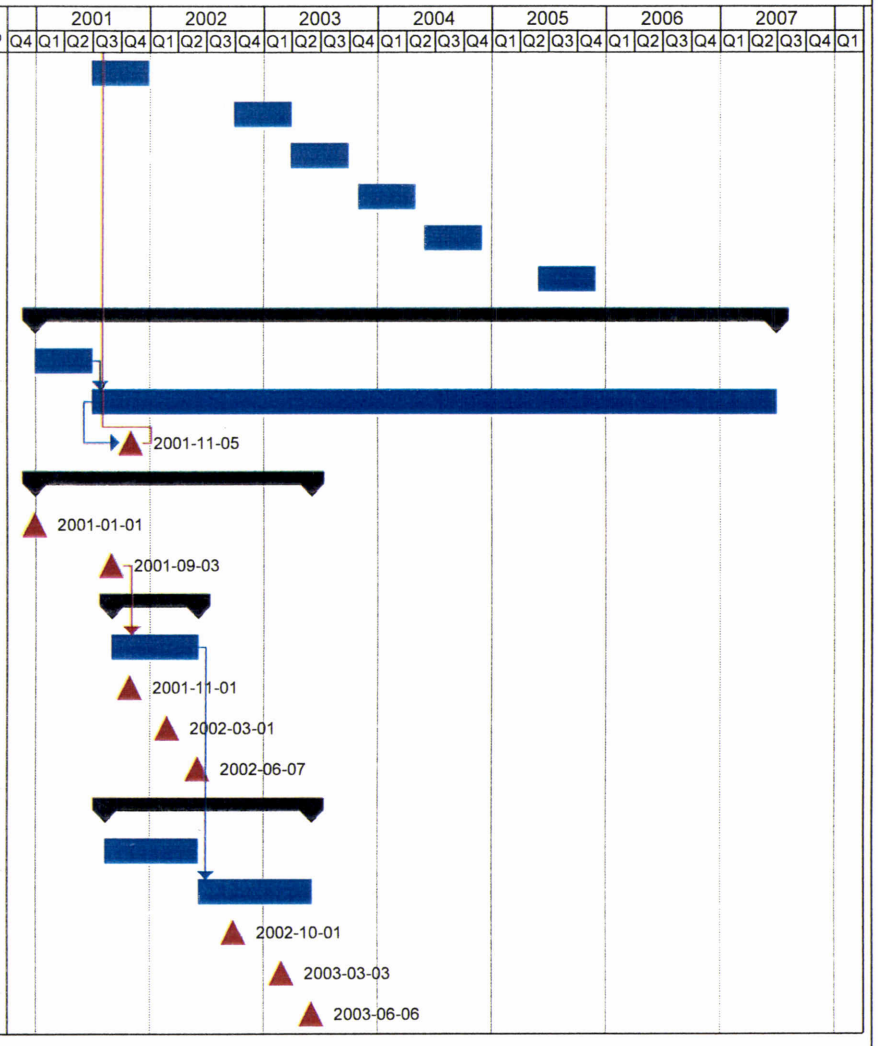

Milestones: **bold type**
Summary Tasks: **underline**

Task Milestone Summary

# MMA Construction Tasks

**All Tasks selected**

| WBS (f) | Task | Start | Finish | CostData? |
|---|---|---|---|---|
| 4.3.8.9 | Build 602-720 GHz Test Plates | 2001-07-02 | 2001-12-28 | Yes |
| 4.3.8.10 | Build 275-370 GHz Test Plates | 2002-10-01 | 2003-03-31 | Yes |
| 4.3.8.11 | Build 89-116 GHz Test Plates | 2003-04-01 | 2003-09-29 | Yes |
| 4.3.8.12 | Build 163-211 GHz Test Plates | 2003-11-03 | 2004-04-30 | Yes |
| 4.3.8.13 | Build 385-500 GHz Test Plates | 2004-06-01 | 2004-11-29 | Yes |
| 4.3.8.14 | Build 125-163 GHz Test Plates | 2005-06-01 | 2005-11-29 | Yes |
| **4.3.9** | **IF Amplifiers** | **2001-01-02** | **2007-07-02** | **No** |
| 4.3.9.1 | Obtain and evaluate InP IF amplifier wafers | 2001-01-02 | 2001-07-02 | Yes |
| 4.3.9.2 | Build IF amplifiers | 2001-07-03 | 2007-07-02 | Yes |
| 4.3.9.3 | Deliver IF Amplifiers for PPR | 2001-11-05 | 2001-11-05 | No |
| **4.4** | **HFET Detector Modules** | **2001-01-01** | **2003-06-06** | **No** |
| 4.4.1 | Contract for HFET Wafer | 2001-01-01 | 2001-01-01 | Yes |
| 4.4.2 | Receive and evaluate InP LNA Wafer | 2001-09-03 | 2001-09-03 | Yes |
| **4.4.3** | **31-45 GHz HFET Detector Module** | **2001-09-03** | **2002-06-07** | **No** |
| 4.4.3.1 | Build 31-45 GHz HFET Detector Modules | 2001-09-03 | 2002-06-07 | Yes |
| 4.4.3.2 | Deliver 31-45 GHz HFET Detector Modules #1-14 | 2001-11-01 | 2001-11-01 | No |
| 4.4.3.3 | Deliver 31-45 GHz HFET Detector Modules #15-52 | 2002-03-01 | 2002-03-01 | No |
| 4.4.3.4 | Deliver 31-45 GHz HFET Detector Modules #53-80 | 2002-06-07 | 2002-06-07 | No |
| **4.4.4** | **67-90 GHz HFET Detector Module** | **2001-08-13** | **2003-06-06** | **No** |
| 4.4.4.1 | Design 67-90 GHz amplifier | 2001-08-13 | 2002-06-07 | Yes |
| 4.4.4.2 | Build 67-90 GHz HFET Detector Modules | 2002-06-10 | 2003-06-06 | Yes |
| 4.4.4.3 | Deliver 67-90 GHz HFET Detector Modules #1-14 | 2002-10-01 | 2002-10-01 | No |
| 4.4.4.4 | Deliver 67-90 GHz HFET Detector Modules #15-52 | 2003-03-03 | 2003-03-03 | No |
| 4.4.4.5 | Deliver 67-90 GHz HFET Detector Modules #53-80 | 2003-06-06 | 2003-06-06 | No |



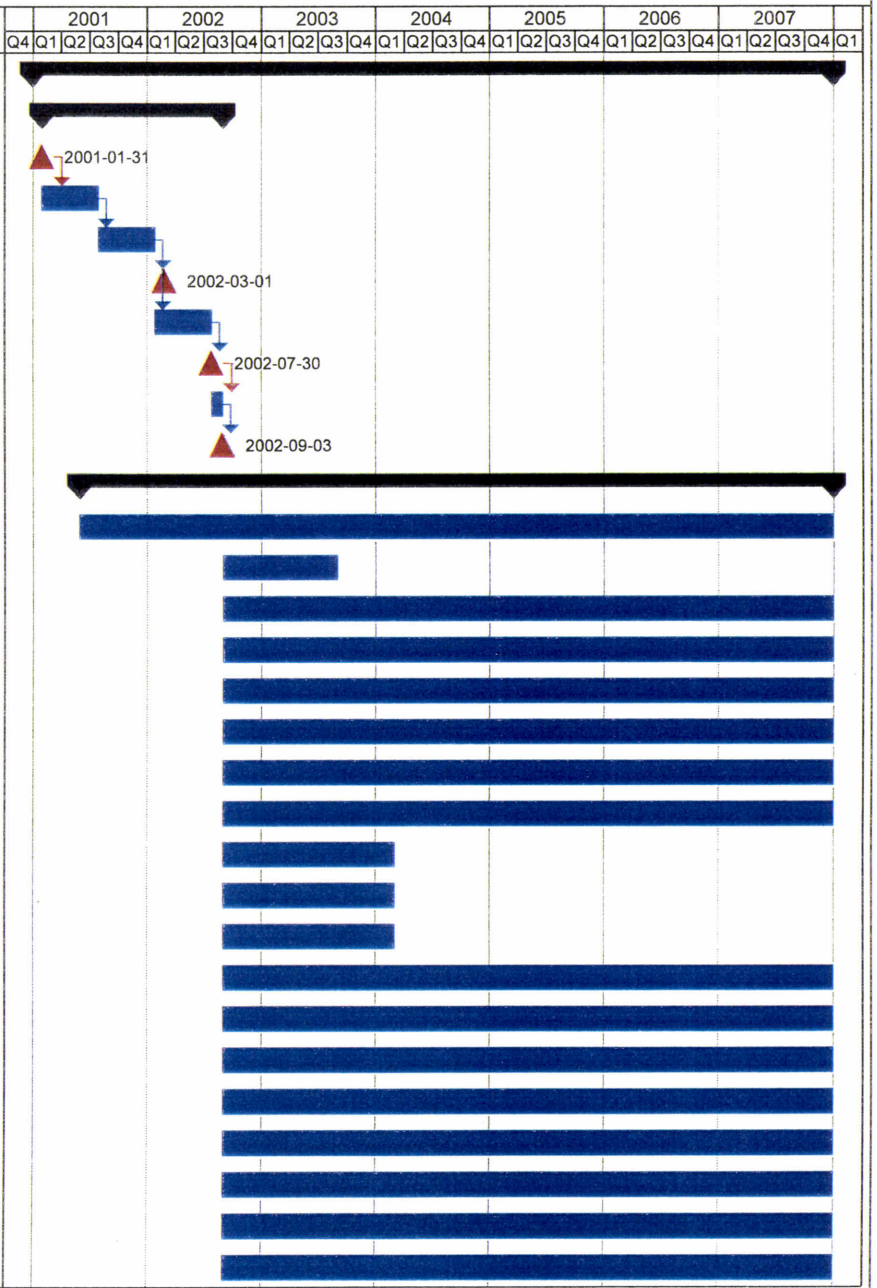

Milestones: **bold type**
Summary Tasks: underline

Task Milestone Summary

# MMA Construction Tasks

**All Tasks selected**

| WBS (f) | Task | Start | Finish | CostData? |
|---|---|---|---|---|
| 5 | **LO System** | 2001-01-01 | 2008-01-01 | No |
| 5.1 | **LO Reference: Prototype Systems** | 2001-01-31 | 2002-09-03 | Yes |
| 5.1.1 | **Deliver: Bench Prototype** | 2001-01-31 | 2001-01-31 | No |
| 5.1.2 | Testing and Design Refinement | 2001-01-31 | 2001-07-31 | No |
| 5.1.3 | Procure/Fab Field Prototypes | 2001-08-01 | 2002-01-29 | No |
| 5.1.4 | **Deliver: LO Ref Field Prototypes** | 2002-03-01 | 2002-03-01 | No |
| 5.1.5 | Field Prototype testing and Design Refinement | 2002-01-30 | 2002-07-30 | No |
| 5.1.6 | **Preproduction Review** | 2002-07-30 | 2002-07-30 | No |
| 5.1.7 | Final Documentation and Design Modifications | 2002-07-31 | 2002-09-03 | No |
| 5.1.8 | **Release for Manufacture** | 2002-09-03 | 2002-09-03 | No |
| 5.2 | **LO Reference: Production System** | 2001-06-01 | 2008-01-01 | No |
| 5.2.1 | Production test and lab equipment | 2001-06-01 | 2008-01-01 | Yes |
| 5.2.2 | H-maser Frequency Standard (& Rb) | 2002-09-05 | 2003-09-03 | Yes |
| 5.2.3 | 8 GHz PL Oscillator & Distributor | 2002-09-05 | 2008-01-01 | Yes |
| 5.2.4 | 10 GHz PL Oscillator & Distributor | 2002-09-05 | 2008-01-01 | Yes |
| 5.2.5 | 12 GHz PL Oscillator & Distributor | 2002-09-05 | 2008-01-01 | Yes |
| 5.2.6 | 14 GHz PL Oscillator & Distributor | 2002-09-05 | 2008-01-01 | Yes |
| 5.2.7 | 3.2-5.2 GHz Synthesizer | 2002-09-05 | 2008-01-01 | Yes |
| 5.2.8 | 3.2 -5.2 GHz PLO and Fringe Generator | 2002-09-05 | 2008-01-01 | Yes |
| 5.2.9 | Sampler Clock 4 GHz PL Osc & Distributor | 2002-09-05 | 2004-03-03 | Yes |
| 5.2.10 | LO Ref Generator | 2002-09-05 | 2004-03-03 | Yes |
| 5.2.11 | LO Ref Distributor - Control Bldg | 2002-09-05 | 2004-03-03 | Yes |
| 5.2.12 | Microwave Round-trip Phase Measurement | 2002-09-05 | 2008-01-01 | Yes |
| 5.2.13 | 10-15 GHz Frequency Synthesizer | 2002-09-05 | 2008-01-01 | Yes |
| 5.2.14 | First LO Fringe Generator | 2002-09-05 | 2008-01-01 | Yes |
| 5.2.15 | 16 GHz PL Oscillator & Distributor | 2002-09-05 | 2008-01-01 | Yes |
| 5.2.16 | 26 GHz PL Oscillator & Distributor | 2002-09-05 | 2008-01-01 | Yes |
| 5.2.17 | LO Ref Distributor - Antenna | 2002-09-05 | 2008-01-01 | Yes |
| 5.2.18 | VXCO Clean-up Loop | 2002-09-05 | 2008-01-01 | Yes |
| 5.2.19 | Power supply module | 2002-09-05 | 2008-01-01 | Yes |



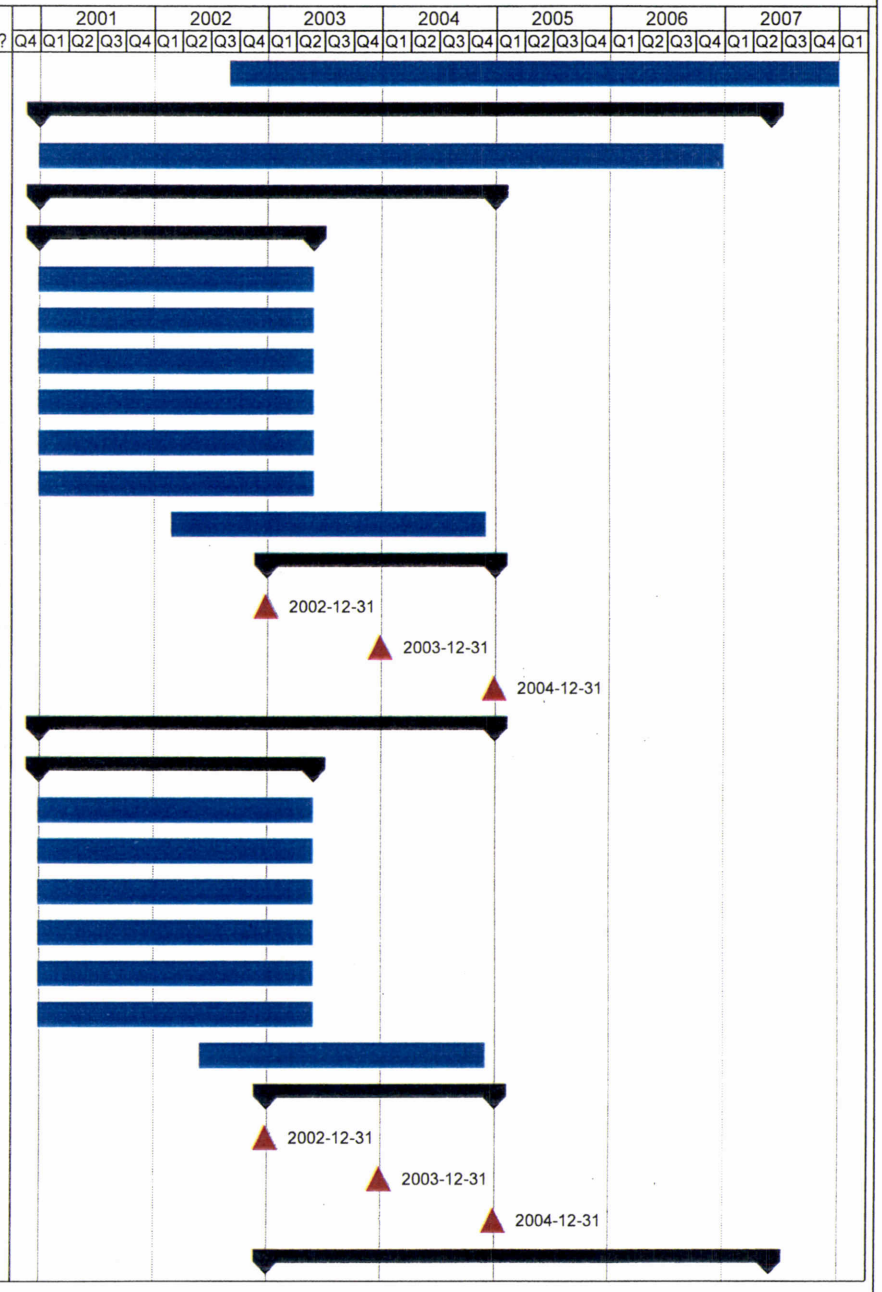

Milestones: **bold type**
Summary Tasks: underline

Task Milestone Summary

# MMA Construction Tasks

**All Tasks selected**

| WBS (f) | Task | Start | Finish | CostData? |
|---|---|---|---|---|
| 5.2.20 | Bins / Racks (assemble and test) | 2002-09-05 | 2008-01-01 | Yes |
| 5.3 | **Millimeter LO Drivers** | 2001-01-01 | 2007-05-31 | No |
| 5.3.1 | LO Source Design and System Integration | 2001-01-01 | 2006-12-28 | Yes |
| 5.3.2 | **72-95 GHz Source** | 2001-01-01 | 2004-12-31 | No |
| 5.3.2.1 | **72-95 GHz LO Source Procurement & Fabrication** | 2001-01-01 | 2003-05-31 | Yes |
| 5.3.2.1.1 | YIG-tuned Oscillator | 2001-01-01 | 2003-05-31 | No |
| 5.3.2.1.2 | 18.00 - 23.75 GHz 10 db Amplifier | 2001-01-01 | 2003-05-30 | No |
| 5.3.2.1.3 | 18.00 - 23.75 GHz x2 Multiplier | 2001-01-01 | 2003-05-30 | No |
| 5.3.2.1.4 | 36.0 - 47.5 GHz 10 db Amplifier | 2001-01-01 | 2003-05-30 | No |
| 5.3.2.1.5 | 36.0 - 47.5 GHz x2 Multiplier | 2001-01-01 | 2003-05-30 | No |
| 5.3.2.1.6 | Mount and Tuning circuitry | 2001-01-01 | 2003-05-30 | No |
| 5.3.2.2 | 72-95 GHz LO Source Assembly & Test | 2002-03-01 | 2004-11-30 | Yes |
| 5.3.2.3 | **Deliver 72-95 GHz LO Sources** | 2002-12-31 | 2004-12-31 | No |
| 5.3.2.3.1 | **Deliver Modules #1-6** | 2002-12-31 | 2002-12-31 | No |
| 5.3.2.3.2 | **Deliver Modules #7-24** | 2003-12-31 | 2003-12-31 | No |
| 5.3.2.3.3 | **Deliver Modules #25-40** | 2004-12-31 | 2004-12-31 | No |
| 5.3.3 | **100-120 GHz Source** | 2001-01-01 | 2004-12-31 | No |
| 5.3.3.1 | **102-120 GHz LO Source Procurement & Fabrication** | 2001-01-01 | 2003-05-30 | Yes |
| 5.3.3.1.1 | YIG-tuned Oscillator | 2001-01-01 | 2003-05-30 | No |
| 5.3.3.1.2 | 25.00 - 30.00 GHz 10 db Amplifier | 2001-01-01 | 2003-05-30 | No |
| 5.3.3.1.3 | 15.00 - 30.00 GHz x2 Multiplier | 2001-01-01 | 2003-05-30 | No |
| 5.3.3.1.4 | 50.0 - 60.0 GHz 10 db Amplifier | 2001-01-01 | 2003-05-30 | No |
| 5.3.3.1.5 | 50-60 GHz x2 Multiplier | 2001-01-01 | 2003-05-30 | No |
| 5.3.3.1.6 | Mount and Tuning circuitry | 2001-01-01 | 2003-05-30 | No |
| 5.3.3.2 | 102-120 GHz LO Source Assembly & Test | 2002-06-03 | 2004-11-30 | Yes |
| 5.3.3.3 | **Deliver 100-120 GHz LO Sources** | 2002-12-31 | 2004-12-31 | No |
| 5.3.3.3.1 | **Deliver Modules #1-3** | 2002-12-31 | 2002-12-31 | No |
| 5.3.3.3.2 | **Deliver Modules #4-21** | 2003-12-31 | 2003-12-31 | No |
| 5.3.3.3.3 | **Deliver Modules #22-40** | 2004-12-31 | 2004-12-31 | No |
| 5.3.4 | **87 - 108 GHz Source** | 2003-01-01 | 2007-05-31 | No |



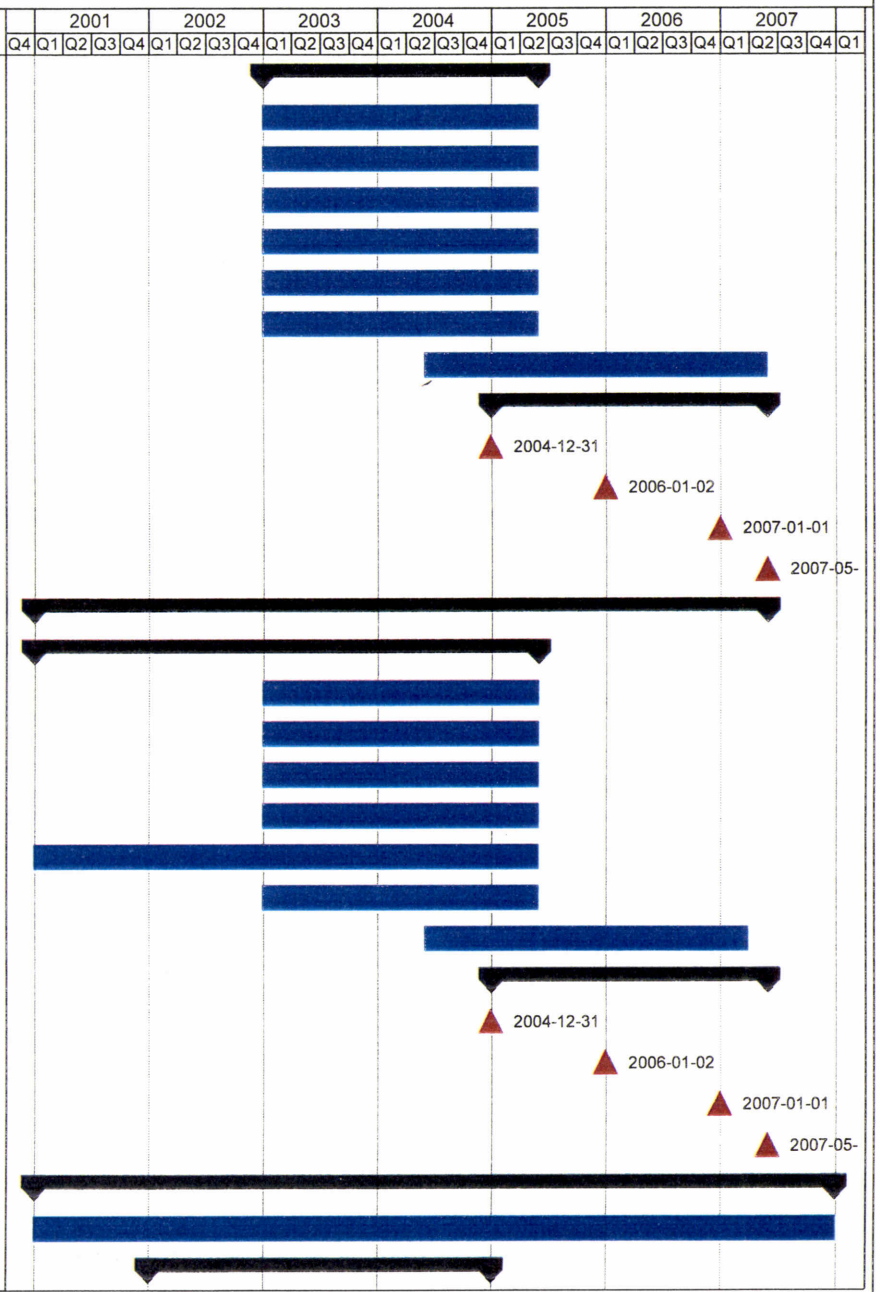

Milestones: **bold type**
Summary Tasks: **underline**

Task Milestone Summary

# MMA Construction Tasks

**All Tasks selected**

| WBS (f) | Task | Start | Finish | CostData? |
|---|---|---|---|---|
| 5.3.4.1 | **87-108 GHz LO Source Procurement & Fabrication** | 2003-01-01 | 2005-05-30 | Yes |
| 5.3.4.1.1 | YIG-tuned Oscillator | 2003-01-01 | 2005-05-30 | No |
| 5.3.4.1.2 | 21.75-27.00 GHz 10 db Amplifier | 2003-01-01 | 2005-05-30 | No |
| 5.3.4.1.3 | 21.75-27.00 GHz x2 Multiplier | 2003-01-01 | 2005-05-30 | No |
| 5.3.4.1.4 | 43.5-54.0 GHz 10 db Amplifier | 2003-01-01 | 2005-05-30 | No |
| 5.3.4.1.5 | 43.5-54.0 GHz x2 Multiplier | 2003-01-01 | 2005-05-30 | No |
| 5.3.4.1.6 | Mount and Tuning Circuitry | 2003-01-01 | 2005-05-30 | No |
| 5.3.4.2 | 87-108 GHz LO Source Assembly & Test | 2004-06-01 | 2007-05-30 | Yes |
| 5.3.4.3 | **Deliver 87-108 GHz LO Sources** | 2004-12-31 | 2007-05-31 | No |
| 5.3.4.3.1 | **Deliver Modules #1-6** | 2004-12-31 | 2004-12-31 | No |
| 5.3.4.3.2 | **Deliver Modules #7-20** | 2006-01-02 | 2006-01-02 | No |
| 5.3.4.3.3 | **Deliver Modules #21-35** | 2007-01-01 | 2007-01-01 | No |
| 5.3.4.3.4 | **Deliver Modules #36-40** | 2007-05-31 | 2007-05-31 | No |
| 5.3.5 | **65 - 85 GHz Source** | 2001-01-01 | 2007-05-31 | No |
| 5.3.5.1 | **65-86 GHz LO Source Procurement & Fabrication** | 2001-01-01 | 2005-05-30 | Yes |
| 5.3.5.1.1 | YIG-tuned Oscillator | 2003-01-01 | 2005-05-30 | No |
| 5.3.5.1.2 | 16.25-21.25 GHz 10 db Amplifier | 2003-01-01 | 2005-05-30 | No |
| 5.3.5.1.3 | 16.25-21.25 GHz x2 Multiplier | 2003-01-01 | 2005-05-30 | No |
| 5.3.5.1.4 | 32.5-42.5 GHz 10 db Amplifier | 2003-01-01 | 2005-05-30 | No |
| 5.3.5.1.5 | 32..5-42.5 GHz x2 Multiplier | 2001-01-01 | 2005-05-30 | No |
| 5.3.5.1.6 | Mount and Tuning Circuitry | 2003-01-01 | 2005-05-30 | No |
| 5.3.5.2 | 65-86 GHz LO Source Assembly & Test | 2004-06-01 | 2007-03-29 | Yes |
| 5.3.5.3 | **Deliver 65-85 GHz LO Sources** | 2004-12-31 | 2007-05-31 | No |
| 5.3.5.3.1 | **Deliver Modules #1-6** | 2004-12-31 | 2004-12-31 | No |
| 5.3.5.3.2 | **Deliver Modules #7-20** | 2006-01-02 | 2006-01-02 | No |
| 5.3.5.3.3 | **Deliver Modules #21-35** | 2007-01-01 | 2007-01-01 | No |
| 5.3.5.3.4 | **Deliver Modules #36-40** | 2007-05-31 | 2007-05-31 | No |
| 5.4 | **Millimeter LO Multiplier Chains** | 2001-01-01 | 2007-12-28 | No |
| 5.4.1 | LO Multiplier Chain Design & System Integration | 2001-01-01 | 2007-12-28 | Yes |
| 5.4.2 | **211 - 275 GHz Receiver LO** | 2002-01-01 | 2004-12-31 | No |



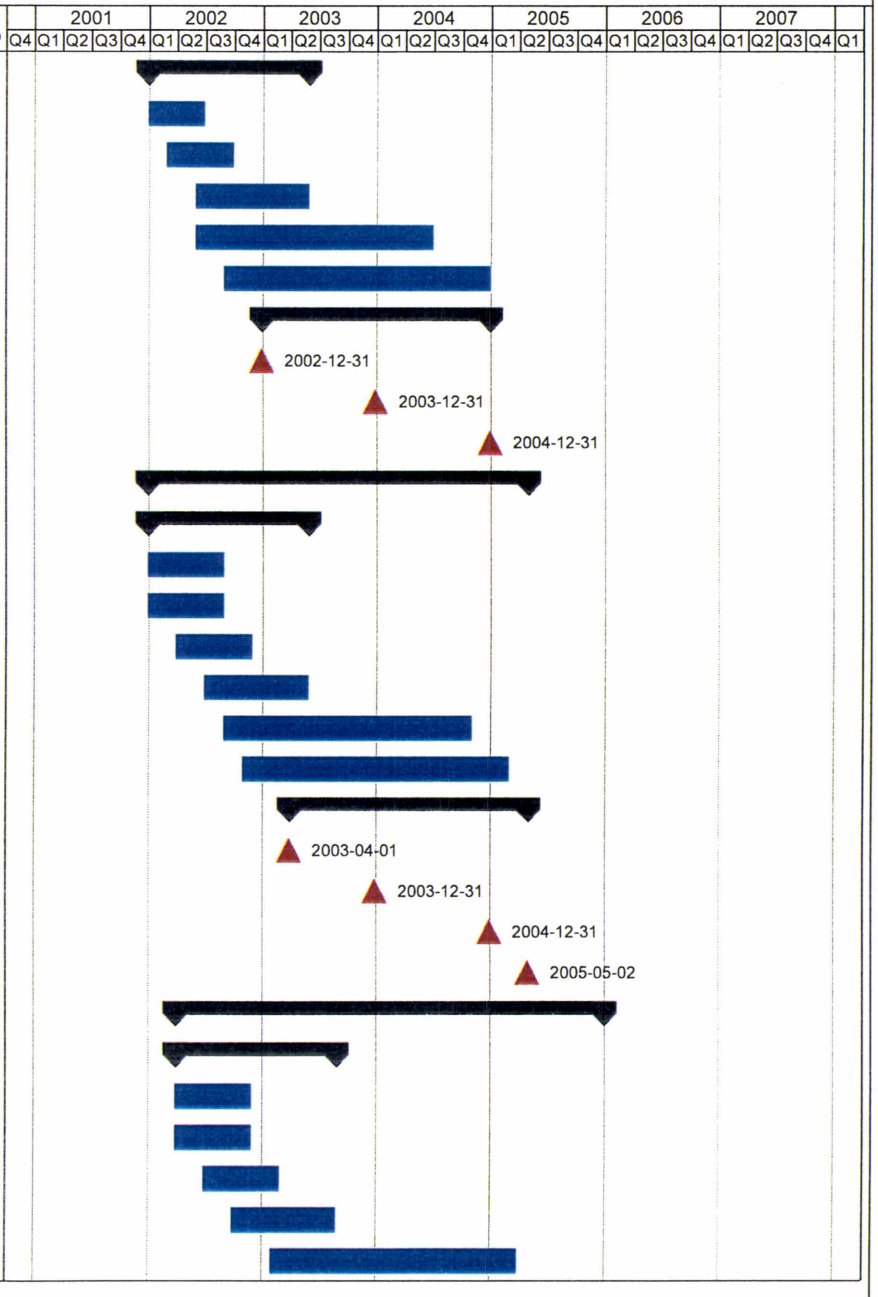

Milestones: **bold type**
Summary Tasks: underline

Task Milestone Summary

# MMA Construction Tasks

**All Tasks selected**

| WBS (f) | Task | Start | Finish | CostData? |
|---|---|---|---|---|
| **5.4.2.1** | **211-275 GHz Receiver LO multiplier Parts** | **2002-01-01** | **2003-05-30** | **Yes** |
| 5.4.2.1.1 | X3 Diode for 72-95 GHz Source | 2002-01-01 | 2002-06-28 | No |
| 5.4.2.1.2 | Machine Mount | 2002-03-01 | 2002-09-30 | No |
| 5.4.2.1.3 | Bias and Control circuits | 2002-06-03 | 2003-05-30 | No |
| 5.4.2.2 | 211-275 GHz Receiver LO Multiplier Assembly & Test | 2002-06-03 | 2004-06-30 | Yes |
| 5.4.2.3 | 275-370 GHz LO integrate source & multiplier | 2002-09-02 | 2004-12-31 | Yes |
| **5.4.2.4** | **Deliver 211-275 GHz Rcvr LO Modules** | **2002-12-31** | **2004-12-31** | **No** |
| **5.4.2.4.1** | **Deliver Modules #1-3** | **2002-12-31** | **2002-12-31** | **No** |
| **5.4.2.4.2** | **Deliver Modules #4-21** | **2003-12-31** | **2003-12-31** | **No** |
| **5.4.2.4.3** | **Deliver Modules #22-40** | **2004-12-31** | **2004-12-31** | **No** |
| **5.4.3** | **602 - 720 GHz Receiver LO** | **2002-01-01** | **2005-05-02** | **No** |
| **5.4.3.1** | **602-720 GHz Receiver LO multiplier Parts** | **2002-01-01** | **2003-05-30** | **Yes** |
| 5.4.3.1.1 | X2 Diode for 100-120 GHz Source | 2002-01-01 | 2002-08-30 | No |
| 5.4.3.1.2 | X3 Diode for 200-240 GHz Input | 2002-01-01 | 2002-08-30 | No |
| 5.4.3.1.3 | Machine Mount | 2002-04-01 | 2002-11-29 | No |
| 5.4.3.1.4 | Bias and Control circuits | 2002-07-01 | 2003-05-30 | No |
| 5.4.3.2 | 602-720 GHz Receiver LO multiplier Assembly & Test | 2002-09-02 | 2004-11-01 | Yes |
| 5.4.3.3 | 602-720 GHz LO integrate source & multiplier | 2002-11-01 | 2005-02-28 | Yes |
| **5.4.3.4** | **Deliver 602-720 GHz Rcvr LO Modules** | **2003-04-01** | **2005-05-02** | **No** |
| **5.4.3.4.1** | **Deliver Modules #1-6** | **2003-04-01** | **2003-04-01** | **No** |
| **5.4.3.4.2** | **Deliver Modules #7-18** | **2003-12-31** | **2003-12-31** | **No** |
| **5.4.3.4.3** | **Deliver Modules #19-34** | **2004-12-31** | **2004-12-31** | **No** |
| **5.4.3.4.4** | **Deliver Modules #35-40** | **2005-05-02** | **2005-05-02** | **No** |
| **5.4.4** | **275 - 370 GHz Receiver LO** | **2002-04-01** | **2006-01-02** | **No** |
| **5.4.4.1** | **275-370 GHz Receiver LO multiplier Parts** | **2002-04-01** | **2003-08-29** | **Yes** |
| 5.4.4.1.1 | X2 Diode for 72-95 GHz Source | 2002-04-01 | 2002-11-29 | No |
| 5.4.4.1.2 | X2 Diode for 144-190 GHz Input | 2002-04-01 | 2002-11-29 | No |
| 5.4.4.1.3 | Machine Mount | 2002-07-01 | 2003-02-28 | No |
| 5.4.4.1.4 | Bias and Control Circuits | 2002-10-01 | 2003-08-29 | No |
| 5.4.4.2 | 275-370 GHz Receiver LO multiplier Assembly & Test | 2003-02-03 | 2005-03-29 | Yes |



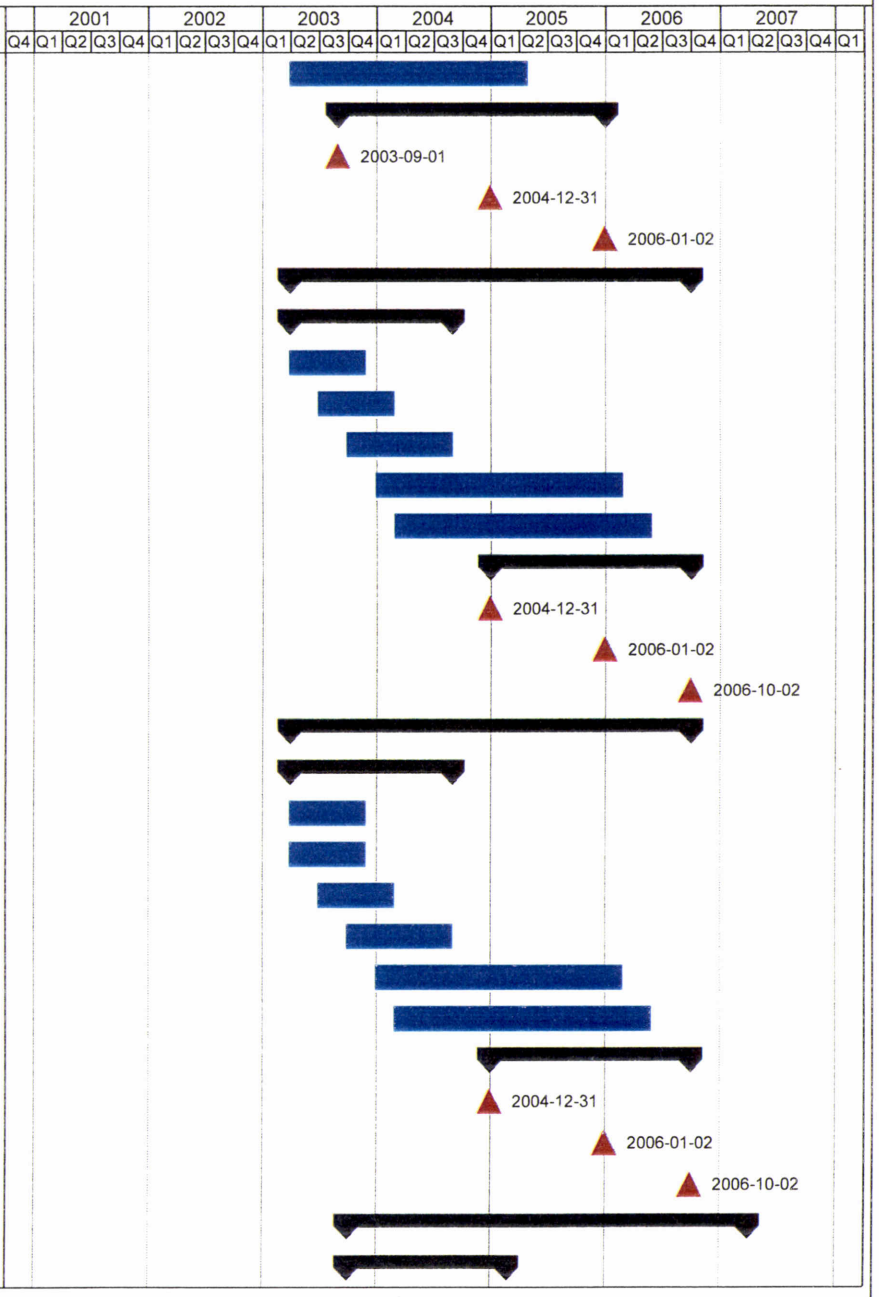

Milestones: **bold type**
Summary Tasks: **underline**

Task Milestone Summary

# MMA Construction Tasks

**All Tasks selected**

| WBS (f) | Task | Start | Finish | CostData? |
|---|---|---|---|---|
| 5.4.4.3 | 275-370 GHz LO integrate source & multiplier | 2003-04-01 | 2005-04-28 | Yes |
| 5.4.4.4 | **Deliver 275-370 GHz Rcvr LO Modules** | 2003-09-01 | 2006-01-02 | No |
| 5.4.4.4.1 | **Deliver Modules #1-6** | 2003-09-01 | 2003-09-01 | No |
| 5.4.4.4.2 | **Deliver Modules #7-27** | 2004-12-31 | 2004-12-31 | No |
| 5.4.4.4.3 | **Deliver Modules #28-40** | 2006-01-02 | 2006-01-02 | No |
| 5.4.5 | **163 - 211 GHz Receiver LO** | 2003-04-01 | 2006-10-02 | No |
| 5.4.5.1 | **163-211 GHz Receiver LO multiplier Parts** | 2003-04-01 | 2004-08-31 | Yes |
| 5.4.5.1.1 | X2 Diode for 87-108 GHz Source | 2003-04-01 | 2003-11-28 | No |
| 5.4.5.1.2 | Machine Mount | 2003-07-01 | 2004-02-27 | No |
| 5.4.5.1.3 | Bias and Control Circuits | 2003-10-01 | 2004-08-31 | No |
| 5.4.5.2 | 163-211 GHz Receiver LO multiplier Assembly & Test | 2004-01-01 | 2006-02-27 | Yes |
| 5.4.5.3 | 163-211 GHz LO integrate source & multiplier | 2004-03-01 | 2006-05-30 | Yes |
| 5.4.5.4 | **Deliver 163 - 211 GHz Rcvr LO Modules** | 2004-12-31 | 2006-10-02 | No |
| 5.4.5.4.1 | **Deliver Modules #1-6** | 2004-12-31 | 2004-12-31 | No |
| 5.4.5.4.2 | **Deliver Modules #7-24** | 2006-01-02 | 2006-01-02 | No |
| 5.4.5.4.3 | **Deliver Modules #25-40** | 2006-10-02 | 2006-10-02 | No |
| 5.4.6 | **385 - 500 GHz Receiver LO** | 2003-04-01 | 2006-10-02 | No |
| 5.4.6.1 | **385-500 GHz Receiver LO multiplier Parts** | 2003-04-01 | 2004-08-31 | Yes |
| 5.4.6.1.1 | X3 Diode for 65-85 GHz Source | 2003-04-01 | 2003-11-28 | No |
| 5.4.6.1.2 | X2 Diode for 130-170 GHz Input | 2003-04-01 | 2003-11-28 | No |
| 5.4.6.1.3 | Machine Mount | 2003-07-01 | 2004-02-27 | No |
| 5.4.6.1.4 | Bias and Control Circuits | 2003-10-01 | 2004-08-31 | No |
| 5.4.6.2 | 385-500 GHz Receiver LO multiplier Assembly & Test | 2004-01-01 | 2006-02-27 | Yes |
| 5.4.6.3 | 385-500 GHz LO integrate source & multiplier | 2004-03-01 | 2006-05-30 | Yes |
| 5.4.6.4 | **Deliver 385-500 GHz Rcvr LO Modules** | 2004-12-31 | 2006-10-02 | No |
| 5.4.6.4.1 | **Deliver Modules #1-6** | 2004-12-31 | 2004-12-31 | No |
| 5.4.6.4.2 | **Deliver Modules #7-24** | 2006-01-02 | 2006-01-02 | No |
| 5.4.6.4.3 | **Deliver Modules #25-40** | 2006-10-02 | 2006-10-02 | No |
| 5.4.7 | **125 - 163 GHz Receiver LO** | 2003-10-01 | 2007-04-02 | No |
| 5.4.7.1 | **125-163 GHz Receiver LO multiplier Parts** | 2003-10-01 | 2005-02-25 | Yes |



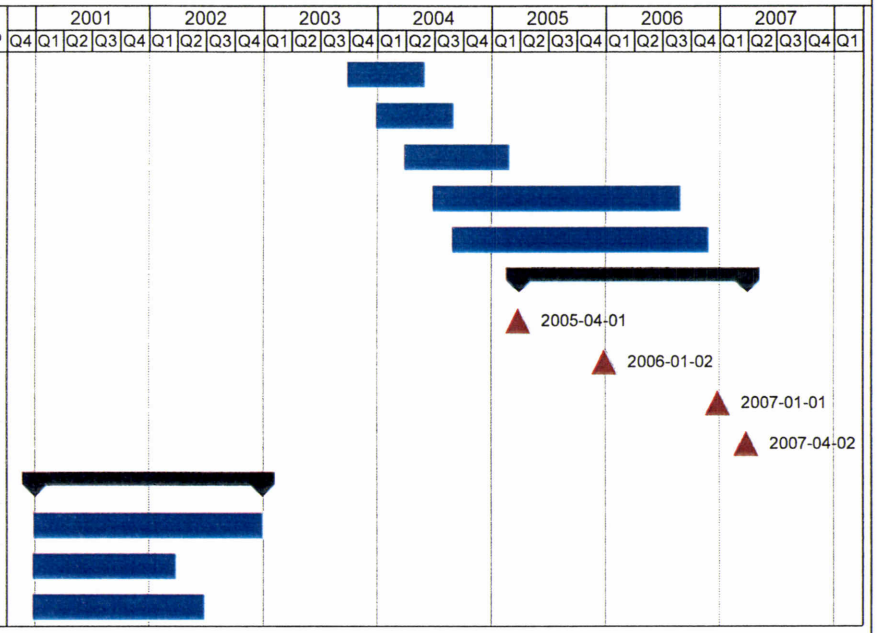

Milestones: **bold type**
Summary Tasks: **underline**

Task Milestone Summary

# MMA Construction Tasks

**All Tasks selected**

| WBS (f) | Task | Start | Finish | CostData? |
|---|---|---|---|---|
| 5.4.7.1.1 | X2 Diode for 65 - 85 GHz Source | 2003-10-01 | 2004-05-31 | No |
| 5.4.7.1.2 | Machine Mount | 2004-01-01 | 2004-08-31 | No |
| 5.4.7.1.3 | Bias and Control Circuits | 2004-04-01 | 2005-02-25 | No |
| 5.4.7.2 | 125-163 GHz Receiver LO multiplier Assembly & Test | 2004-07-01 | 2006-08-30 | Yes |
| 5.4.7.3 | 125-163 GHz LO integrate source & multiplier | 2004-09-01 | 2006-11-29 | Yes |
| **5.4.7.4** | **Deliver 125-163 GHz Rcvr LO Modules** | **2005-04-01** | **2007-04-02** | **No** |
| **5.4.7.4.1** | **Deliver Modules #1-6** | **2005-04-01** | **2005-04-01** | **No** |
| **5.4.7.4.2** | **Deliver Modules #7-18** | **2006-01-02** | **2006-01-02** | **No** |
| **5.4.7.4.3** | **Deliver Modules #19-34** | **2007-01-01** | **2007-01-01** | **No** |
| **5.4.7.4.4** | **Deliver Modules #35-40** | **2007-04-02** | **2007-04-02** | **No** |
| **5.4.8** | **33-45 GHz Receiver LO** | **2001-01-03** | **2002-12-31** | **No** |
| 5.4.8.1 | Design & fab 31-45 GHz receiver LO coupling | 2001-01-03 | 2002-12-31 | Yes |
| 5.4.9 | LO Multiplier Fabrication Equipment | 2001-01-01 | 2002-03-29 | Yes |
| 5.4.10 | LO Multiplier Test Equipment | 2001-01-01 | 2002-06-28 | Yes |



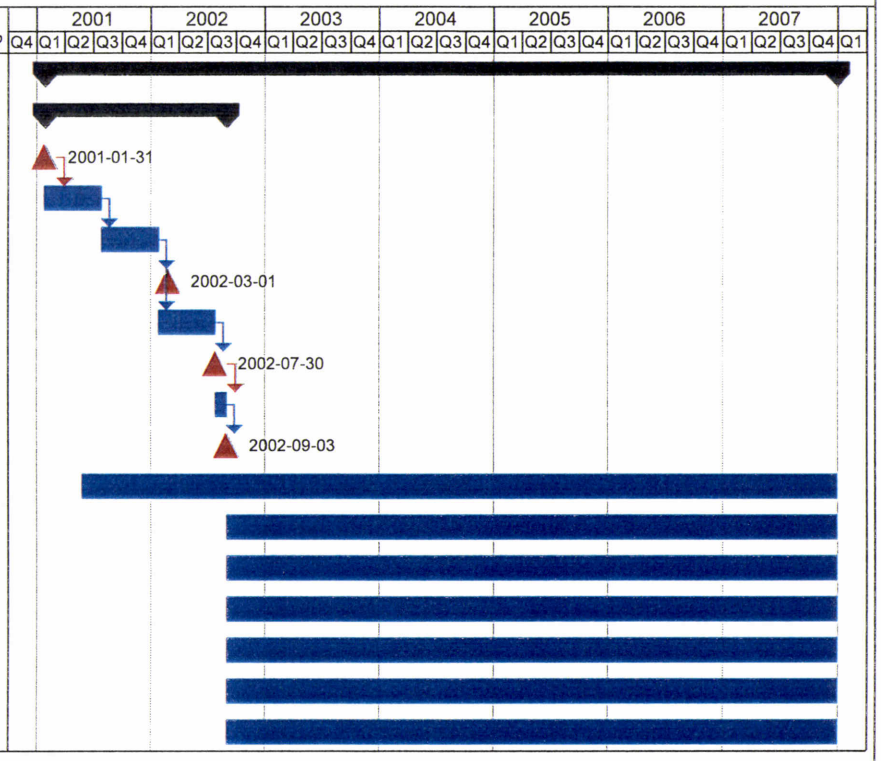

Milestones: **bold type**
Summary Tasks: **underline**

Task Milestone Summary

# MMA Construction Tasks

**All Tasks selected**

| WBS (f) | Task | Start | Finish | CostData? |
|---|---|---|---|---|
| 6 | **IF System** | 2001-01-31 | 2008-01-01 | No |
| 6.1 | **IF Field Prototype for Test Interferometer of 2 antennas.** | 2001-01-31 | 2002-09-03 | Yes |
| 6.1.1 | **Deliver (Bench) Prototype IF System** | 2001-01-31 | 2001-01-31 | No |
| 6.1.2 | Testing and Design Refinement | 2001-01-31 | 2001-07-31 | No |
| 6.1.3 | Procure/Fab Field Prototypes | 2001-08-01 | 2002-01-29 | No |
| 6.1.4 | **Deliver IF Field Prototypes to Test Interfeometer** | 2002-03-01 | 2002-03-01 | No |
| 6.1.5 | Field Prototype testing and Design Refinement | 2002-01-30 | 2002-07-30 | No |
| 6.1.6 | **Preproduction Review** | 2002-07-30 | 2002-07-30 | No |
| 6.1.7 | Final Documentation and Design Modifications | 2002-07-31 | 2002-09-03 | No |
| 6.1.8 | **Release for Manufacture** | 2002-09-03 | 2002-09-03 | No |
| 6.2 | IF Construction test & lab equipment | 2001-05-31 | 2008-01-01 | Yes |
| 6.3 | IF Multiplexer (2/antenna) | 2002-09-05 | 2008-01-01 | Yes |
| 6.4 | IF Demultiplexer (2/antenna) | 2002-09-05 | 2008-01-01 | Yes |
| 6.5 | IF Matrix Switch (2/antenna) | 2002-09-05 | 2008-01-01 | Yes |
| 6.6 | IF Baseband Converter (8/antenna) | 2002-09-05 | 2008-01-01 | Yes |
| 6.7 | IF Power Supply module | 2002-09-05 | 2008-01-01 | Yes |
| 6.8 | Bins / Racks (assemble and test) | 2002-09-05 | 2008-01-01 | Yes |



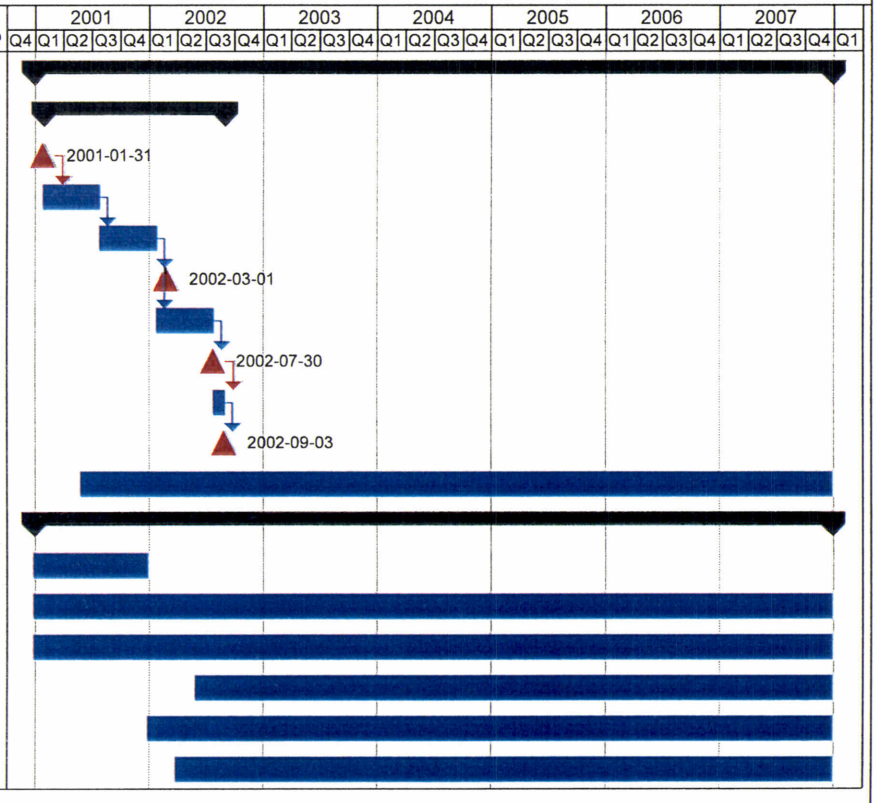

Milestones: **bold type**
Summary Tasks: **underline**

Task Milestone Summary

# MMA Construction Tasks

**All Tasks selected**

| WBS (f) | Task | Start | Finish | CostData? |
|---|---|---|---|---|
| 7 | **Optical Fiber System** | 2001-01-01 | 2007-12-31 | No |
| 7.1 | **Prototype Optical Fiber Systems** | 2001-01-31 | 2002-09-03 | Yes |
| 7.1.1 | **Deliver (Bench) Prototype FO System** | 2001-01-31 | 2001-01-31 | No |
| 7.1.2 | Testing and Design Refinement | 2001-01-31 | 2001-07-31 | No |
| 7.1.3 | Procure/Fab Field Prototypes | 2001-08-01 | 2002-01-29 | No |
| 7.1.4 | **Deliver FO Field Prototypes to Test Interfeometer** | 2002-03-01 | 2002-03-01 | No |
| 7.1.5 | Field Prototype testing and Design Refinement | 2002-01-30 | 2002-07-30 | No |
| 7.1.6 | **Preproduction Review** | 2002-07-30 | 2002-07-30 | No |
| 7.1.7 | Final Documentation and Design Modifications | 2002-07-31 | 2002-09-03 | No |
| 7.1.8 | **Release for Manufacture** | 2002-09-03 | 2002-09-03 | No |
| 7.2 | Digital IF Transmitters and Receivers | 2001-06-01 | 2007-12-31 | Yes |
| 7.3 | **16 GHz FO LO Reference Distribution** | 2001-01-01 | 2007-12-31 | No |
| 7.3.1 | 16 GHZ FO LO Ref Dist Prototype | 2001-01-01 | 2001-12-31 | Yes |
| 7.3.2 | 16 GHz FO LO Ref Dist with Integrated R/T Phase Meas. | 2001-01-01 | 2007-12-31 | Yes |
| 7.4 | Production Test Equipment | 2001-01-01 | 2007-12-31 | Yes |
| 7.5 | Monitor and Control Transmitters and Receivers | 2002-06-03 | 2007-12-31 | Yes |
| 7.6 | Fiber Optics Power Supply Modules | 2002-01-01 | 2007-12-31 | Yes |
| 7.7 | Bins / Racks (assemble and test) | 2002-04-01 | 2007-12-31 | Yes |



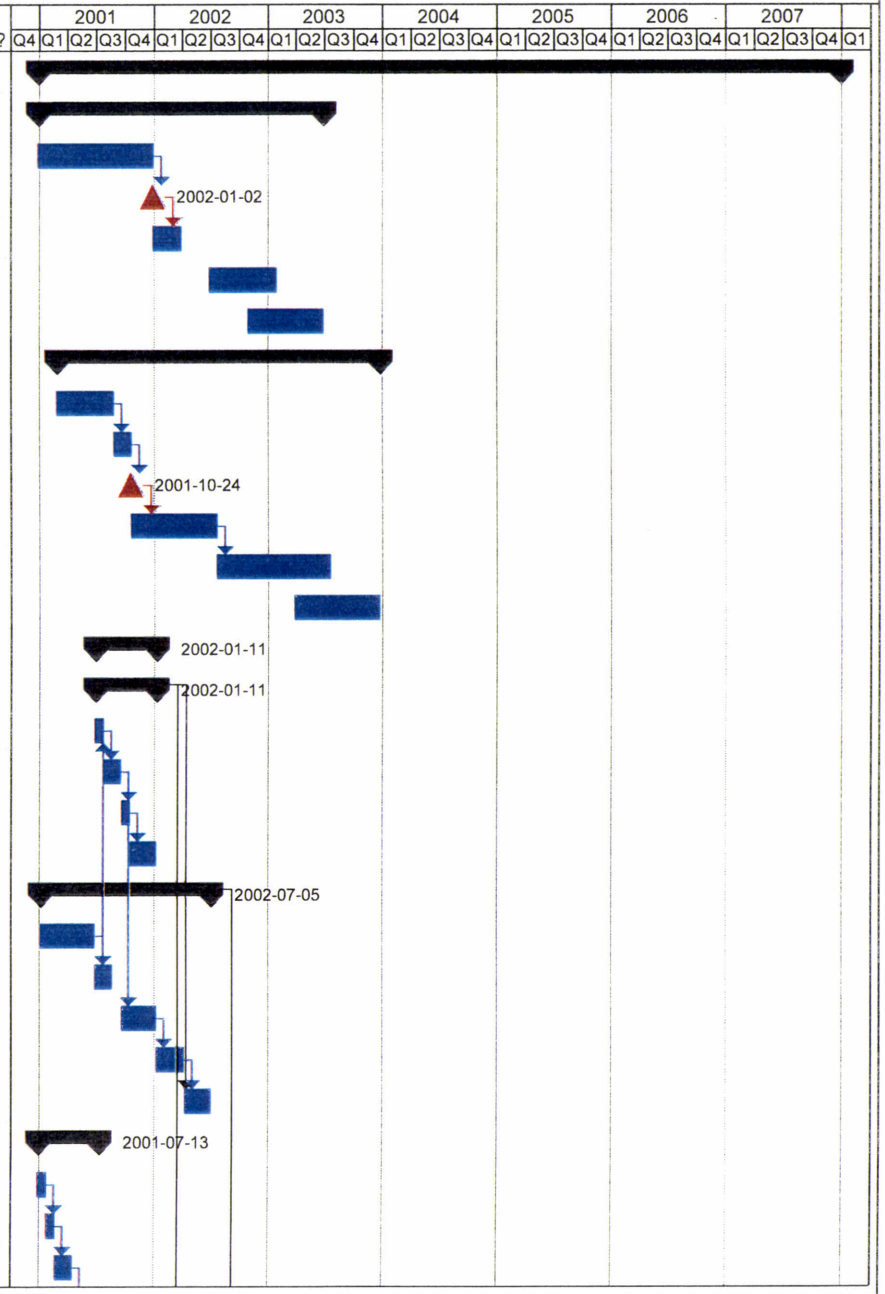

Milestones: **bold type**
Summary Tasks: **underline**

Task Milestone Summary

# MMA Construction Tasks

**All Tasks selected**

| WBS (f) | Task | Start | Finish | CostData? |
|---|---|---|---|---|
| 8 | **Correlator** | 2001-01-01 | 2008-01-01 | No |
| 8.1 | **Digital Sampler, 4 GHz** | 2001-01-01 | 2003-06-30 | No |
| 8.1.1 | Refine digitizer design | 2001-01-01 | 2002-01-02 | Yes |
| 8.1.2 | **Release Digital Sampler for Manufacture** | 2002-01-02 | 2002-01-02 | No |
| 8.1.3 | Digitizer contract materials | 2002-01-03 | 2002-04-02 | Yes |
| 8.1.4 | Assembly of digitizers | 2002-07-01 | 2003-01-31 | Yes |
| 8.1.5 | Digitizer validation and delivery | 2002-11-01 | 2003-06-30 | Yes |
| 8.2 | **Digital FIR Filter** | 2001-03-01 | 2003-12-26 | No |
| 8.2.1 | Prototype FIR filter testing on interferometer | 2001-03-01 | 2001-08-29 | Yes |
| 8.2.2 | Design & test FIR filter refinement | 2001-08-30 | 2001-10-24 | Yes |
| 8.2.3 | **Release FIR Filter for manufacture** | 2001-10-24 | 2001-10-24 | No |
| 8.2.4 | FIR filter chip & board fabrication | 2001-10-25 | 2002-07-24 | Yes |
| 8.2.5 | FIR filter board assembly | 2002-07-25 | 2003-07-23 | Yes |
| 8.2.6 | FIR filter board validation and delivery | 2003-03-31 | 2003-12-26 | Yes |
| 8.3 | **Custom Boards** | 2001-07-02 | 2002-01-11 | No |
| 8.3.1 | **Correlator boards** | 2001-07-02 | 2002-01-11 | Yes |
| 8.3.1.1 | Prototype assembly | 2001-07-02 | 2001-07-27 | No |
| 8.3.1.2 | Prototype test | 2001-07-30 | 2001-09-21 | No |
| 8.3.1.3 | Design modifications | 2001-09-24 | 2001-10-19 | No |
| 8.3.1.4 | Fab, assemble and test with design mods | 2001-10-22 | 2002-01-11 | No |
| 8.4 | **Correlator Chip** | 2001-01-08 | 2002-07-05 | Yes |
| 8.4.1 | Prototype chip fabrication | 2001-01-08 | 2001-07-01 | No |
| 8.4.2 | Prototype chip test | 2001-07-02 | 2001-08-24 | No |
| 8.4.3 | Design modifications | 2001-09-24 | 2002-01-11 | No |
| 8.4.4 | Fabricate and test design mods | 2002-01-14 | 2002-04-12 | No |
| 8.4.5 | Fabricate production run | 2002-04-15 | 2002-07-05 | No |
| 8.5 | **Correlator Racks** | 2001-01-01 | 2001-07-13 | Yes |
| 8.5.1 | Design control wiring | 2001-01-01 | 2001-01-26 | No |
| 8.5.2 | Design signal wiring | 2001-01-29 | 2001-02-23 | No |
| 8.5.3 | Order parts | 2001-02-26 | 2001-04-20 | No |



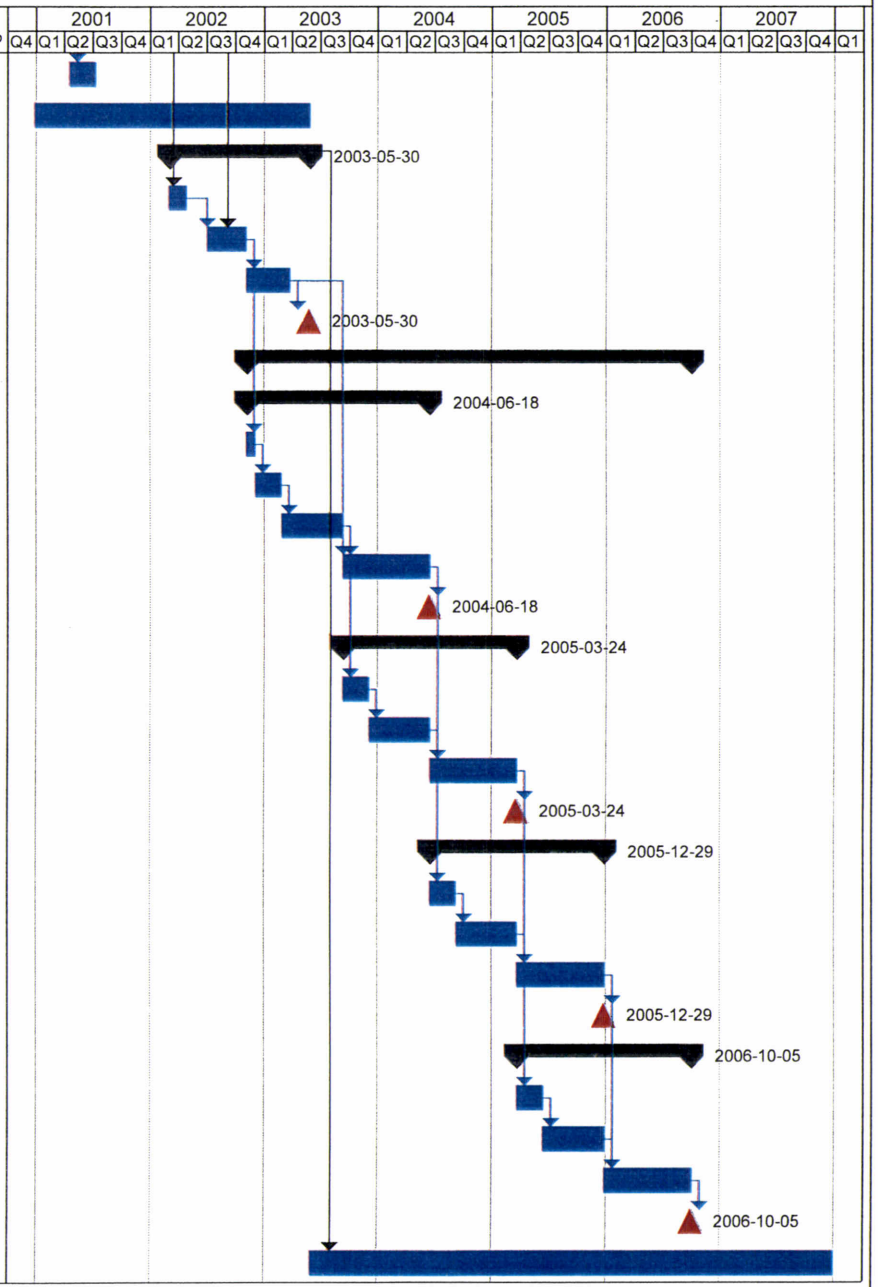

Milestones: **bold type**
Summary Tasks: **underline**

Task Milestone Summary

# MMA Construction Tasks

**All Tasks selected**

| WBS (f) | Task | Start | Finish | CostData? |
|---|---|---|---|---|
| 8.5.4 | Assemble prototypes | 2001-04-23 | 2001-07-13 | No |
| 8.6 | Correlator software | 2001-01-01 | 2003-05-30 | Yes |
| **8.7** | **Prototype Correlator Production** | 2002-03-07 | 2003-05-30 | **Yes** |
| 8.7.1 | Order parts | 2002-03-07 | 2002-05-01 | No |
| 8.7.2 | Assemble | 2002-07-08 | 2002-11-08 | No |
| 8.7.3 | Test | 2002-11-11 | 2003-03-28 | No |
| **8.7.4** | **Deliver Prototype Correlator to VLA site** | 2003-05-30 | 2003-05-30 | **No** |
| **8.8** | **Site Correlator Production** | 2002-11-11 | 2006-10-05 | **No** |
| **8.8.1** | **First 1/4 correlator** | 2002-11-11 | 2004-06-18 | **Yes** |
| 8.8.1.1 | Determine configuration | 2002-11-11 | 2002-12-06 | No |
| 8.8.1.2 | Order parts | 2002-12-09 | 2003-02-28 | No |
| 8.8.1.3 | Assemble | 2003-03-03 | 2003-09-12 | No |
| 8.8.1.4 | Test | 2003-09-15 | 2004-06-18 | No |
| **8.8.1.5** | **Deliver 1/4 Correlator to MMA site** | 2004-06-18 | 2004-06-18 | **No** |
| **8.8.2** | **Second 1/4 correlator** | 2003-09-15 | 2005-03-24 | **Yes** |
| 8.8.2.1 | Order parts | 2003-09-15 | 2003-12-05 | No |
| 8.8.2.2 | Assemble | 2003-12-08 | 2004-06-18 | No |
| 8.8.2.3 | Test | 2004-06-21 | 2005-03-24 | No |
| **8.8.2.4** | **Deliver 1/4 Correlator to MMA site** | 2005-03-24 | 2005-03-24 | **No** |
| **8.8.3** | **Third 1/4 correlator** | 2004-06-21 | 2005-12-29 | **Yes** |
| 8.8.3.1 | Order parts | 2004-06-21 | 2004-09-10 | No |
| 8.8.3.2 | Assemble | 2004-09-13 | 2005-03-24 | No |
| 8.8.3.3 | Test | 2005-03-25 | 2005-12-29 | No |
| **8.8.3.4** | **Deliver 1/4 Correlator to MMA site** | 2005-12-29 | 2005-12-29 | **No** |
| **8.8.4** | **Fourth 1/4 correlator** | 2005-03-25 | 2006-10-05 | **Yes** |
| 8.8.4.1 | Order parts | 2005-03-25 | 2005-06-16 | No |
| 8.8.4.2 | Assemble | 2005-06-17 | 2005-12-29 | No |
| 8.8.4.3 | Test | 2005-12-30 | 2006-10-05 | No |
| **8.8.4.4** | **Deliver 1/4 Correlator to MMA site** | 2006-10-05 | 2006-10-05 | **No** |
| 8.9 | Correlator Test Equipment | 2003-06-03 | 2008-01-01 | Yes |



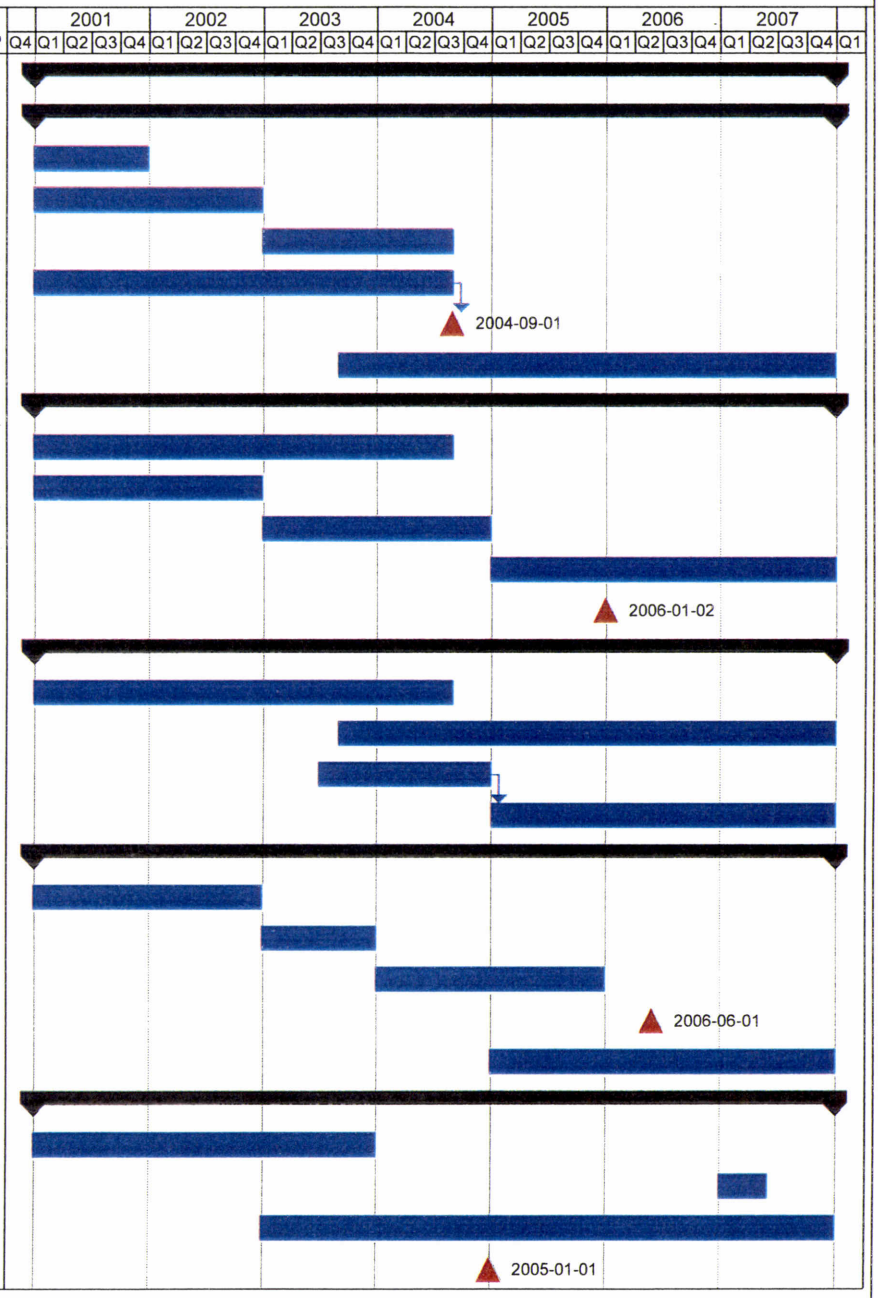

Milestones: **bold type**
Summary Tasks: **underline**

Task Milestone Summary

# MMA Construction Tasks

**All Tasks selected**

| WBS (f) | Task | Start | Finish | CostData? |
|---|---|---|---|---|
| 9 | **Computing** | 2001-01-01 | 2008-01-01 | Yes |
| 9.1 | **Control Software** | 2001-01-01 | 2008-01-01 | Yes |
| 9.1.1 | Test Interferometer Control and Analysis | 2001-01-01 | 2002-01-01 | Yes |
| 9.1.2 | MMA correlator software | 2001-01-01 | 2003-01-01 | Yes |
| 9.1.3 | Multi-antenna & sub-array control | 2003-01-01 | 2004-09-01 | Yes |
| 9.1.4 | Operators and Observers Interfaces | 2001-01-01 | 2004-09-01 | Yes |
| 9.1.5 | **Deliver Control Software** | 2004-09-01 | 2004-09-01 | Yes |
| 9.1.6 | Maintenance | 2003-09-02 | 2008-01-01 | Yes |
| 9.2 | **Scheduling** | 2001-01-01 | 2008-01-01 | Yes |
| 9.2.1 | Static scheduling system | 2001-01-01 | 2004-09-01 | Yes |
| 9.2.2 | Dynamic scheduling simulations | 2001-01-01 | 2003-01-01 | Yes |
| 9.2.3 | Dynamic scheduling prototype | 2003-01-01 | 2004-12-31 | Yes |
| 9.2.4 | Dynamic scheduling implementation | 2004-12-30 | 2008-01-01 | Yes |
| 9.2.5 | **Initial Operations with Dynamic Scheduling** | 2006-01-02 | 2006-01-02 | No |
| 9.3 | **Proposal Preparation Software** | 2001-01-01 | 2008-01-01 | Yes |
| 9.3.1 | Proposal assistance prototype | 2001-01-01 | 2004-08-31 | Yes |
| 9.3.2 | Proposal assistance implementation | 2003-09-02 | 2008-01-01 | Yes |
| 9.3.3 | Observe program prototype | 2003-07-01 | 2005-01-01 | Yes |
| 9.3.4 | Observe program | 2005-01-03 | 2008-01-01 | Yes |
| 9.4 | **Image Pipeline** | 2001-01-01 | 2008-01-01 | Yes |
| 9.4.1 | Automated calibration & imaging heuristics | 2001-01-01 | 2003-01-01 | Yes |
| 9.4.2 | Prototype image pipeline | 2003-01-01 | 2004-01-01 | Yes |
| 9.4.3 | Parallelization studies and implementation | 2004-01-01 | 2006-01-01 | Yes |
| 9.4.4 | **Initial Image Pipeline Operations** | 2006-06-01 | 2006-06-01 | Yes |
| 9.4.5 | Production image pipeline | 2004-12-30 | 2008-01-01 | Yes |
| 9.5 | **Archiving** | 2001-01-01 | 2008-01-01 | Yes |
| 9.5.1 | Prototype distributed archive | 2001-01-01 | 2004-01-01 | Yes |
| 9.5.2 | Evaluate storage hardware | 2007-01-01 | 2007-06-01 | Yes |
| 9.5.3 | Production archive | 2002-12-31 | 2008-01-01 | Yes |
| 9.5.4 | **Data Archive operational** | 2005-01-01 | 2005-01-01 | No |



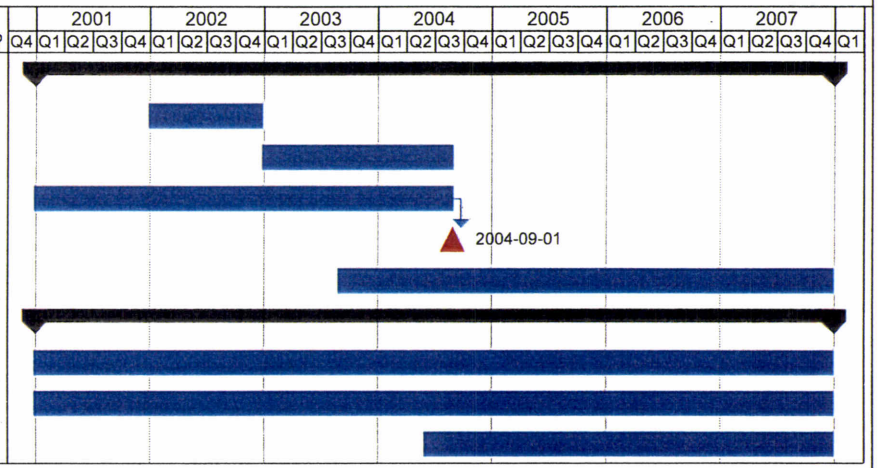

Milestones: **bold type**
Summary Tasks: **underline**

Task Milestone Summary

# MMA Construction Tasks

**All Tasks selected**

| WBS (f) | Task | Start | Finish | CostData? |
|---|---|---|---|---|
| 9.6 | **Post processing** | 2001-01-01 | 2008-01-01 | Yes |
| 9.6.1 | Define data formats | 2002-01-03 | 2003-01-01 | Yes |
| 9.6.2 | Filler and format conversions | 2003-01-01 | 2004-09-01 | Yes |
| 9.6.3 | ALMA specific calibrations | 2001-01-01 | 2004-09-01 | Yes |
| 9.6.4 | **MMA Post-processing begins** | 2004-09-01 | 2004-09-01 | Yes |
| 9.6.5 | Maintenance | 2003-09-01 | 2008-01-01 | Yes |
| 9.7 | **Software support** | 2001-01-01 | 2008-01-01 | Yes |
| 9.7.1 | Tool support | 2001-01-01 | 2008-01-01 | Yes |
| 9.7.2 | Quality assurance | 2001-01-01 | 2008-01-01 | Yes |
| 9.7.3 | Chile system administration | 2004-06-01 | 2008-01-01 | Yes |



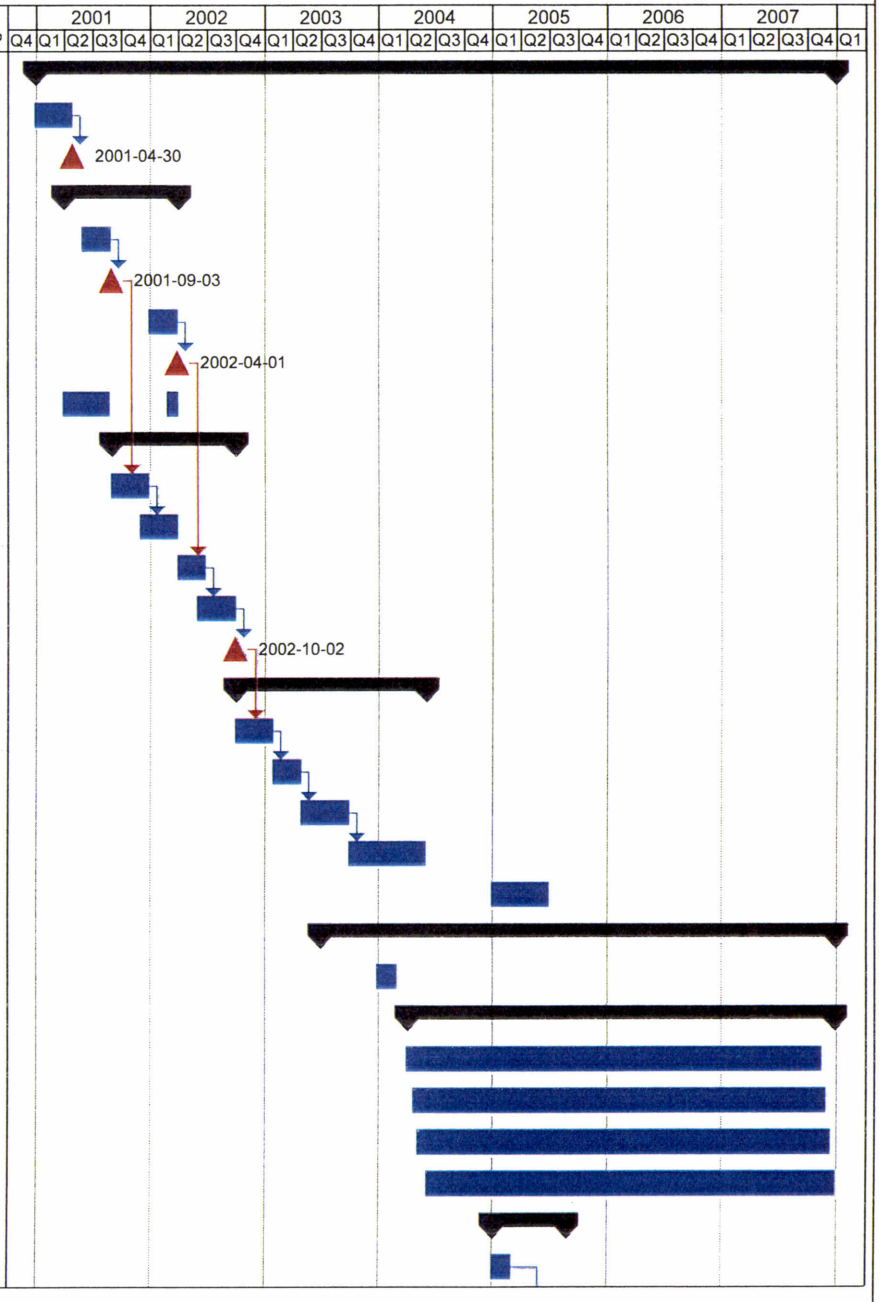

Milestones: **bold type**
Summary Tasks: underline

Task Milestone Summary

# MMA Construction Tasks

**All Tasks selected**

| WBS (f) | Task | Start | Finish | CostData? |
|---|---|---|---|---|
| 10 | **System Integration** | 2001-01-01 | 2007-12-31 | Yes |
| 10.4 | Test Interferometer Site Preparation | 2001-01-01 | 2001-04-30 | Yes |
| 10.5 | **Test Interferometer Site Complete** | 2001-04-30 | 2001-04-30 | No |
| 10.10 | **Outfitting at U.S. test site** | 2001-04-02 | 2002-04-03 | Yes |
| 10.10.4 | Antenna #1 Outfitting | 2001-06-01 | 2001-08-31 | Yes |
| 10.10.5 | **Antenna #1 Outfitting Complete** | 2001-09-03 | 2001-09-03 | No |
| 10.10.7 | Antenna #2 Outfitting | 2002-01-01 | 2002-04-01 | Yes |
| 10.10.8 | **Antenna #2 Outfitting Complete** | 2002-04-01 | 2002-04-01 | No |
| 10.10.10 | General Outfitting | 2001-04-02 | 2002-04-03 | Yes |
| 10.11 | **Single Dish Tests** | 2001-09-03 | 2002-10-02 | Yes |
| 10.11.1 | Ant #1 holography and surface readjustment | 2001-09-03 | 2001-12-31 | Yes |
| 10.11.2 | Ant #1 Antenna Evaluation | 2001-12-04 | 2002-04-02 | Yes |
| 10.11.6 | Ant #2 holography and surface readjustment | 2002-04-02 | 2002-06-28 | Yes |
| 10.11.7 | Ant #2 Antenna Evaluation | 2002-06-03 | 2002-10-02 | Yes |
| 10.11.10 | **Engineering Recommendations re Prod. Ant.** | 2002-10-02 | 2002-10-02 | No |
| 10.12 | **Interferometric Tests** | 2002-10-03 | 2004-06-03 | Yes |
| 10.12.1 | Phase/gain stability tests | 2002-10-03 | 2003-01-30 | Yes |
| 10.12.2 | Sensitivity verification | 2003-01-31 | 2003-05-01 | Yes |
| 10.12.3 | Holography with astronomical sources | 2003-05-02 | 2003-10-02 | Yes |
| 10.12.4 | Modifications and Retrofits | 2003-10-03 | 2004-06-03 | Yes |
| 10.13 | Dissassemble test system and ship to array site | 2005-01-01 | 2005-07-01 | Yes |
| 10.14 | **On-site System Integration** | 2003-07-01 | 2007-12-31 | Yes |
| 10.14.1 | Set up assembly and test facilities at OSF | 2004-01-01 | 2004-03-03 | Yes |
| 10.14.2 | **Outfit antennas 3 through 36** | 2004-04-05 | 2007-12-28 | Yes |
| 10.14.2.1 | Wiring and plumbing | 2004-04-05 | 2007-11-16 | Yes |
| 10.14.2.2 | Install electronics in receiver cabin | 2004-04-26 | 2007-11-30 | Yes |
| 10.14.2.3 | Check out completed antenna at OSF | 2004-05-10 | 2007-12-14 | Yes |
| 10.14.2.4 | Install antenna at array site. | 2004-06-07 | 2007-12-28 | Yes |
| 10.14.3 | **Refurbish antennas 1 and 2** | 2005-01-03 | 2005-08-26 | Yes |
| 10.14.3.1 | Re-install electronics and upgrade as needed | 2005-01-03 | 2005-03-04 | Yes |



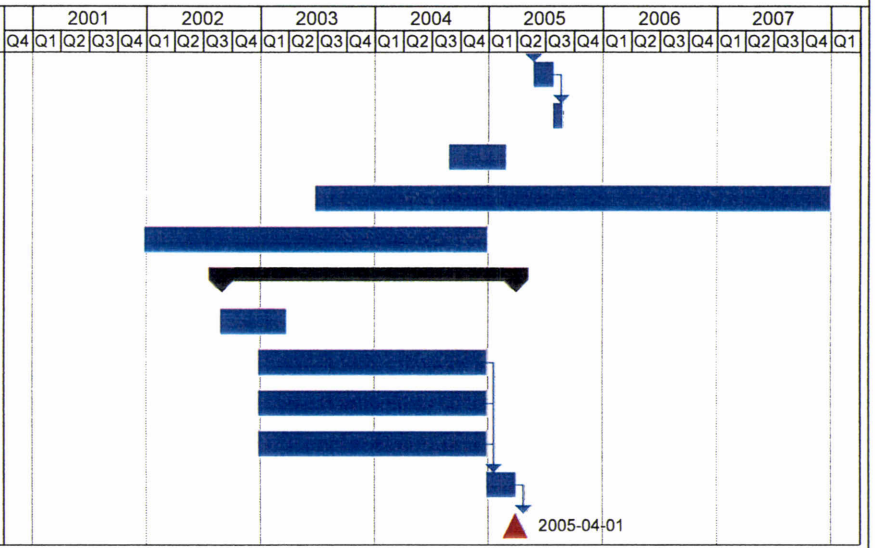

Milestones: **bold type**
Summary Tasks: underline

Task Milestone Summary

# MMA Construction Tasks

**All Tasks selected**

| WBS (f) | Task | Start | Finish | CostData? |
|---|---|---|---|---|
| 10.14.3.2 | Check out at OSF | 2005-05-30 | 2005-07-29 | Yes |
| 10.14.3.3 | Install antenna at array site | 2005-08-01 | 2005-08-26 | Yes |
| 10.14.4 | Install central building electronics | 2004-09-01 | 2005-02-28 | Yes |
| 10.14.5 | Support debugging and repair | 2003-07-01 | 2007-12-31 | Yes |
| 10.20 | Prototype Testing Support | 2002-01-01 | 2004-12-31 | Yes |
| **10.25** | **Operations Personnel Training** | **2002-09-02** | **2005-04-01** | **No** |
| 10.25.1 | Recruit Initial Chile Ops Staff | 2002-09-02 | 2003-03-28 | No |
| 10.25.2 | Array Operations | 2003-01-01 | 2004-12-28 | No |
| 10.25.3 | Engineering Maintenance | 2003-01-01 | 2004-12-28 | No |
| 10.25.4 | Scientific Support & Analysis | 2003-01-01 | 2004-12-28 | No |
| 10.25.5 | Relocate Ops Staff to Chile | 2005-01-01 | 2005-04-01 | No |
| **10.25.6** | **Start On-site Operations** | **2005-04-01** | **2005-04-01** | **No** |



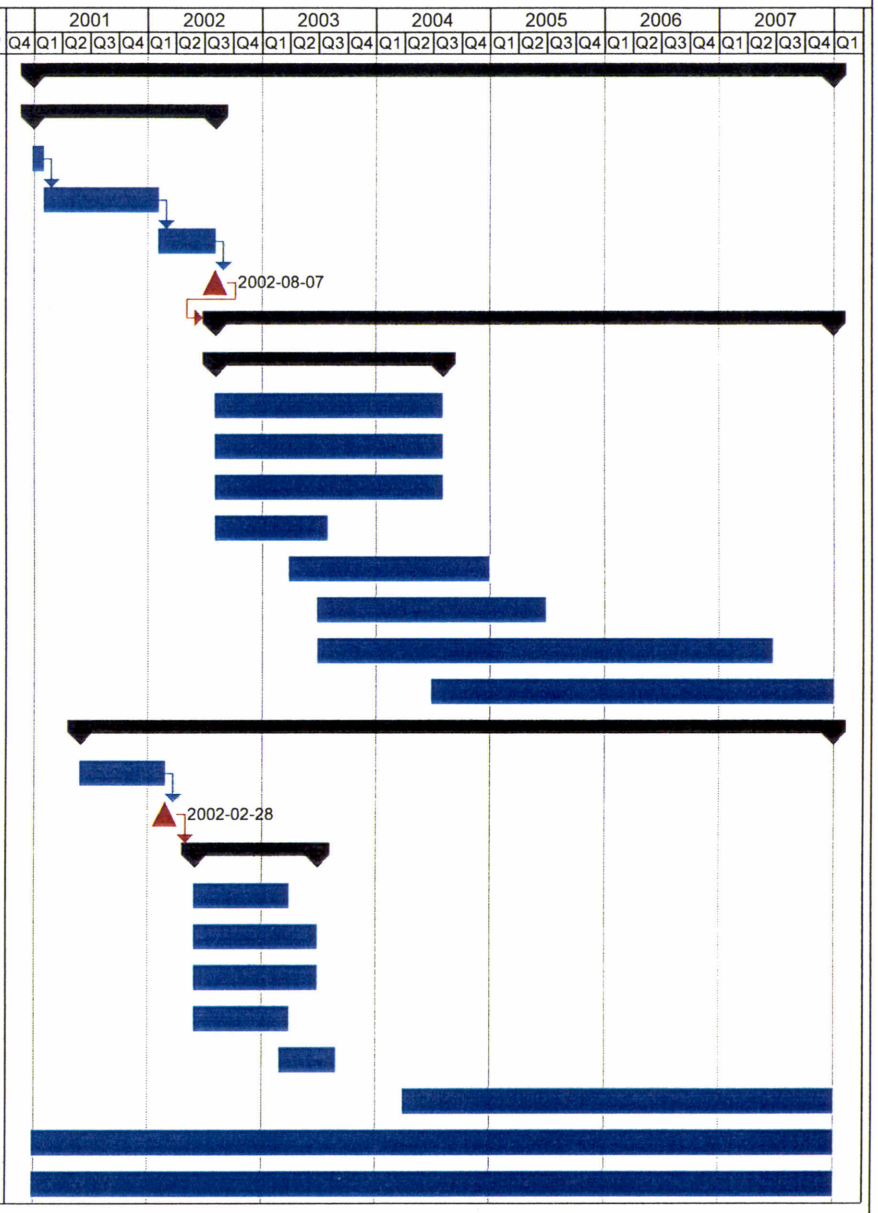

Milestones: **bold type**
Summary Tasks: **underline**

Task Milestone Summary

# MMA Construction Tasks

**All Tasks selected**

| WBS (f) | Task | Start | Finish | CostData? |
|---|---|---|---|---|
| 11 | **Calibration and Imaging** | 2001-01-01 | 2008-01-01 | No |
| 11.1 | **Radiometric Phase Design & Prototype** | 2001-01-01 | 2002-08-07 | No |
| 11.1.1 | Completion of 183 GHz Water Vapor Radiometer | 2001-01-01 | 2001-02-02 | Yes |
| 11.1.2 | Demonstrate 183 GHz Water Vapor Radiometer | 2001-02-05 | 2002-02-06 | Yes |
| 11.1.3 | Refinement of 183 GHz Water Vapor Radiometer | 2002-02-07 | 2002-08-07 | Yes |
| 11.1.4 | **Release WVR for manufacture** | 2002-08-07 | 2002-08-07 | Yes |
| 11.2 | **Production Fab of Phase Monitor Radiometer** | 2002-08-08 | 2008-01-01 | No |
| 11.2.1 | **Contract Subassembly Fabrication** | 2002-08-08 | 2004-08-04 | No |
| 11.2.1.1 | Contract Phase Monitor Radiometer Subassembly | 2002-08-08 | 2004-08-04 | Yes |
| 11.2.1.2 | WVR Spectrometer | 2002-08-08 | 2004-08-04 | Yes |
| 11.2.1.3 | WVR Feed, Window, Lens, Instrumentation | 2002-08-08 | 2004-08-04 | Yes |
| 11.2.1.4 | Monitor and Control WVR Interface | 2002-08-08 | 2003-07-31 | Yes |
| 11.2.2 | Assembly & Test | 2003-04-01 | 2004-12-31 | No |
| 11.2.3 | Deliver Production Radiometers | 2003-06-30 | 2005-06-29 | Yes |
| 11.2.4 | Integration of WVR into Receiver Package | 2003-07-01 | 2007-06-22 | Yes |
| 11.2.5 | Verification on Site of WVR | 2004-07-01 | 2008-01-01 | Yes |
| 11.3 | **Production Fabrication of Dual-load Amp Cal Sys** | 2001-06-01 | 2008-01-01 | No |
| 11.3.1 | Dual-Load Amp. Calibration Device Design Refinement | 2001-06-01 | 2002-02-28 | Yes |
| 11.3.2 | **Release Dual-Load Amp Cal for Mftr** | 2002-02-28 | 2002-02-28 | Yes |
| 11.3.3 | **Contract Subassembly Dual-Load Amp Cal** | 2002-06-03 | 2003-06-30 | Yes |
| 11.3.3.1 | Dual-Load AmpCal Subassy Machining | 2002-06-03 | 2003-03-31 | Yes |
| 11.3.3.2 | Load Fabrication for Dual Load Amp Cal | 2002-06-03 | 2003-06-30 | Yes |
| 11.3.3.3 | Dual Load Amplitude Calibration Device Motors, Servo | 2002-06-03 | 2003-06-30 | Yes |
| 11.3.3.4 | M/C Interface for Dual Load Amp Cal Device | 2002-06-03 | 2003-03-31 | Yes |
| 11.3.4 | Assembly and Test of Dual Load Amplitude Calibration | 2003-03-03 | 2003-08-29 | Yes |
| 11.3.5 | Integration of AmpCal on Production Antennas | 2004-04-02 | 2008-01-01 | Yes |
| 11.4 | Imaging Studies and Project Support | 2001-01-01 | 2008-01-01 | Yes |
| 11.5 | Imaging Algorithm Development | 2001-01-01 | 2008-01-01 | Yes |




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

Task Milestone Summary

# U.S. Cost Estimate Sheets

# Millimeter Array Construction: Project Totals

US Reference Project

| WBS | Task Name | Scientists Work-months | Programmers Work-months | Engineers Work-months | Technicians Work-months | Personnel 1999 $K | Materials & Supplies 1999 $K | Contingency | Total Cost 1999 $K | Inflated Cost $K |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.1 | Project Management | 432 | 0 | 0 | 168 | 3,744 | 0 | 15% | 4,306 | 4,869 |
| 1.1.1 | Management, Planning, and Oversight | 0 | 0 | 0 | 0 | 0 | 4,533 | 15% | 5,213 | 5,935 |
| 1.1.2 | Business Operations | 0 | 0 | 0 | 0 | 0 | 580 | 15% | 667 | 765 |
| 1.1.3 | Chilean Operations | 0 | 0 | 0 | 0 | 0 | 145 | 15% | 167 | 185 |
| 1.1.4 | Safety and Health | 0 | 0 | 0 | 0 | 0 | 0 | 15% | 0 | 0 |
| 1.1.5 | Personnel | 0 | 0 | 0 | 0 | 0 | 0 | 15% | 0 | 0 |
| 1.1.6 | Project Science Office | 0 | 0 | 0 | 0 | 0 | 0 | 15% | 0 | 0 |
| 1.1.7 | AUI Management | 0 | 0 | 0 | 0 | 0 | 2,450 | 15% | 2,817 | 3,192 |
| 1.2 | Engineering | 0 | 0 | 168 | 84 | 1,547 | 140 | 15% | 1,940 | 2,198 |
| 1.2.1 | System Engineering--Phase II | 0 | 0 | 0 | 0 | 0 | 0 | 15% | 0 | 0 |
| 1.2.2 | Documentation System | 0 | 0 | 0 | 0 | 0 | 0 | 15% | 0 | 0 |
| 1.2.3 | Production Engineering | 0 | 0 | 0 | 0 | 0 | 0 | 15% | 0 | 0 |
| 1.3 | US Facilities | 0 | 0 | 0 | 0 | 0 | 0 | 15% | 0 | 0 |
| 1.3.1 | CDL Permanent Facilities | 0 | 0 | 0 | 0 | 0 | 3,000 | 0% | 3,000 | 3,000 |
| 1.3.2 | Manufacturing Facilities | 0 | 0 | 0 | 0 | 0 | 805 | 10% | 886 | 1,003 |
| 1.3.3 | Common Infrastructure | 0 | 0 | 0 | 0 | 0 | 1,400 | 15% | 1,610 | 1,824 |
| | | | | | | | | | | |
| 2 | Site Development | 0 | 0 | 84 | 0 | 610 | 350 | 5% | 1,008 | 1,141 |
| 2.2 | Maintain Mining claims | 0 | 0 | 0 | 0 | 0 | 150 | 5% | 158 | 176 |
| 2.3 | Contract A&E Studies | 0 | 0 | 0 | 0 | 0 | 938 | 20% | 1,126 | 1,183 |
| 2.5.3 | Contract Array Site Civil Works | 0 | 0 | 0 | 0 | 0 | 21,631 | 20% | 25,957 | 28,128 |
| 2.6.3 | Contract OSF Civil Works | 0 | 0 | 0 | 0 | 0 | 14,142 | 20% | 16,970 | 18,389 |
| 2.7.3 | Contract Civil Works | 0 | 0 | 0 | 0 | 0 | 3,830 | 20% | 4,596 | 4,949 |
| 2.8.1 | Equip Array Site | 0 | 0 | 0 | 0 | 0 | 5,830 | 20% | 6,996 | 7,560 |
| 2.8.2 | Equip Operations Support Facility | 0 | 0 | 0 | 0 | 0 | 2,200 | 20% | 2,640 | 2,987 |
| | | | | | | | | | | |
| 3.1 | Antenna Engineering Support | 0 | 0 | 96 | 0 | 697 | 0 | 14% | 794 | 845 |
| 3.8.10 | Sign Transporter Contract | 0 | 0 | 0 | 0 | 0 | 790 | 20% | 948 | 996 |
| 3.8.30 | Accept Transporter #2 at OSF | 0 | 0 | 0 | 0 | 0 | 740 | 20% | 888 | 1,030 |
| 3.8.35 | Contract for Transporter #1 Move to site | 0 | 0 | 0 | 0 | 0 | 20 | 12% | 22 | 26 |
| 3.15 | Procurement of Antenna 2 | 0 | 0 | 0 | 0 | 0 | 3,002 | 27% | 3,813 | 4,006 |
| 3.20 | Sign Contract for Production Antennas | 0 | 0 | 0 | 0 | 0 | 1,615 | 20% | 1,938 | 2,139 |
| 3.21 | Antenna Contract Supervision | 0 | 0 | 102 | 0 | 740 | 0 | 12% | 829 | 956 |
| 3.23 | Accept Antenna #3 at OSF | 0 | 0 | 2 | 0 | 11 | 2,754 | 27% | 3,511 | 3,876 |
| 3.25, 3.27, 3.2 | Accept Antennas #4 through #36 | 0 | 0 | 50 | 0 | 359 | 90,882 | 27% | 115,876 | 137,160 |
| | | | | | | | | | | |
| 4.1.1.2 | Fabricate PPRC | 0 | 0 | 3 | 8 | 53 | 69 | 28% | 156 | 164 |
| 4.1.1.3 | Test PPRC | 0 | 3 | 3 | 3 | 51 | 10 | 5% | 64 | 68 |
| 4.1.2.1 | PPR Dewar Design | 0 | 0 | 4 | 4 | 45 | 0 | 17% | 52 | 55 |
| 4.1.2.2 | PPR Dewar Fabrication and Vacuum Testing | 0 | 0 | 1 | 6 | 31 | 8 | 40% | 54 | 57 |
| 4.1.2.3 | PPR Vacuum Windows and IR Filters | 0 | 0 | 2 | 2 | 22 | 12 | 20% | 41 | 43 |
| 4.1.2.4 | PPR Cryogenics/Dewar Assembly and Testing | 0 | 2 | 2 | 3 | 38 | 18 | 13% | 63 | 67 |
| 4.1.3.1 | PPR Control-Monitoring and Bias Electronics Design | 0 | 0 | 6 | 6 | 67 | 0 | 21% | 81 | 85 |
| 4.1.3.2 | PPR Control-Monitor and Bias Electronics Construction | 0 | 0 | 2 | 5 | 34 | 22 | 44% | 81 | 85 |
| 4.1.4.1 | Insert Mechanical-Thermal Design, Bands <275 GHz (Waveguide | 0 | 0 | 6 | 0 | 44 | 0 | 48% | 64 | 68 |
| 4.1.4.2 | Insert Component Fabrication for Bands <275 GHz | 0 | 0 | 1 | 8 | 38 | 37 | 56% | 118 | 124 |
| 4.1.4.3 | Insert Mechanical-Thermal Design for Bands >275 GHz (Quasi o | 0 | 0 | 6 | 0 | 44 | 0 | 48% | 64 | 68 |
| 4.1.4.4 | Insert Component Fabrication for Bands >275 Ghz | 0 | 0 | 1 | 6 | 31 | 13 | 56% | 67 | 71 |
| 4.1.4.8 | PPR Insert Assembly (3 Bands) | 0 | 0 | 0 | 3 | 12 | 5 | 44% | 24 | 25 |
| 4.1.4.9 | PPR Insert Testing (3 Bands) | 0 | 0 | 2 | 2 | 22 | 0 | 16% | 26 | 27 |
| 4.1.5.1 | PPR Vacuum System Assembly | 0 | 0 | 1 | 1 | 11 | 26 | 8% | 40 | 42 |
| 4.1.7.1 | PPR Post IF System Design | 0 | 0 | 1 | 1 | 11 | 0 | 22% | 14 | 14 |

# Millimeter Array Construction: Project Totals

US Reference Project

| WBS | Task Name | Scientists Work-months | Programmers Work-months | Engineers Work-months | Technicians Work-months | Personnel 1999 $K | Materials & Supplies 1999 $K | Contingency | Total Cost 1999 $K | Inflated Cost $K |
|---|---|---|---|---|---|---|---|---|---|---|
| 4.1.7.2 | PPR Post IF System Construction and Testing | 0 | 0 | 2 | 2 | 22 | 32 | 24% | 67 | 71 |
| 4.1.8.1 | PPR Frame Design | 0 | 0 | 3 | 2 | 30 | 0 | 16% | 34 | 36 |
| 4.1.8.2 | PPR Frame Fabrication | 0 | 0 | 0 | 5 | 20 | 18 | 30% | 49 | 51 |
| 4.1.9.1 | Prototype Production Receiver Integration | 0 | 0 | 3 | 4 | 37 | 10 | 14% | 54 | 57 |
| 4.1.9.2 | PPR Testing and Evaluation | 0 | 3 | 6 | 8 | 93 | 75 | 36% | 228 | 242 |
| 4.1.10.1 | Design and build Prototype and Production Receiver Test Set | 0 | 3 | 6 | 12 | 108 | 444 | 36% | 751 | 789 |
| 4.1.10.2 | Design and Fabricate Receiver Insert Test Set | 0 | 4 | 4 | 8 | 84 | 213 | 11% | 330 | 346 |
| 4.1.10.3 | General Test Equipment | 0 | 0 | 1 | 1 | 11 | 360 | 13% | 419 | 441 |
| 4.2.1 | MMA Receiver (MMA Rx) Design Refinement | 0 | 0 | 6 | 2 | 51 | 0 | 28% | 66 | 71 |
| 4.2.2 | MMA Receiver (MMA Rx) Documentation | 0 | 0 | 4 | 8 | 60 | 10 | 18% | 83 | 88 |
| 4.2.4.1 | MMA Rx Dewar Fabrication | 0 | 0 | 5 | 39 | 188 | 266 | 16% | 527 | 609 |
| 4.2.4.2 | MMA Rx Cryogenics Fabrication | 0 | 0 | 12 | 117 | 543 | 2,508 | 20% | 3,662 | 4,230 |
| 4.2.4.3 | Vacuum Windows and IR Filters Fabrication | 0 | 0 | 12 | 66 | 345 | 346 | 16% | 801 | 910 |
| 4.2.4.4 | Receiver Insert Fabrication | 0 | 0 | 10 | 358 | 1,469 | 3,078 | 22% | 5,547 | 6,415 |
| 4.2.4.5 | MMA Receiver Frame Fabrication and assembly | 0 | 0 | 6 | 78 | 348 | 570 | 16% | 1,065 | 1,230 |
| 4.2.4.6 | Vacuum System Fabrication and testing. | 0 | 0 | 0 | 21 | 82 | 760 | 16% | 977 | 1,119 |
| 4.2.4.7 | Bias and Control-Monitoring Electronics Construction | 0 | 0 | 5 | 18 | 106 | 912 | 16% | 1,181 | 1,353 |
| 4.2.4.9 | Assemble Receiver Inserts and Test | 0 | 0 | 179 | 358 | 2,695 | 2,584 | 20% | 6,335 | 7,295 |
| 4.2.4.10 | Assemble MMA Rx IF System | 0 | 0 | 5 | 21 | 118 | 551 | 14% | 763 | 881 |
| 4.2.6.1 | Integrate Test & Commission MMA Receivers | 0 | 0 | 58 | 117 | 877 | 114 | 16% | 1,150 | 1,330 |
| 4.5.1 | Construct and test Cryo system for 2nd Evaluation Receiver | 0 | 0 | 7 | 11 | 94 | 69 | 16% | 189 | 198 |
| 4.5.2 | Fabrication and assembly of 2nd Evaluation Receiver. | 0 | 3 | 6 | 50 | 256 | 292 | 16% | 636 | 668 |
| 4.5.3 | Test and Commission 2nd Evaluation Receiver | 0 | 0 | 3 | 3 | 33 | 0 | 5% | 35 | 37 |
| 4.3.1.1 | Design, Fab, and Test 211-275 GHz Mixer Design | 0 | 0 | 6 | 7 | 69 | 96 | 52% | 251 | 264 |
| 4.3.1.3 | Fabricate 211-275 GHz mixer blocks | 0 | 0 | 0 | 10 | 39 | 7 | 16% | 53 | 57 |
| 4.3.1.4 | Fabricate & test 211-275 GHz SIS Mixer Detector Modules | 0 | 0 | 18 | 44 | 302 | 558 | 52% | 1,308 | 1,391 |
| 4.3.2.1 | Design, Fab, and Test 602-720 GHz Mixer Design | 0 | 0 | 24 | 38 | 322 | 632 | 52% | 1,451 | 1,524 |
| 4.3.2.3 | Fabricate 602-720 GHz mixer blocks | 0 | 0 | 0 | 14 | 55 | 14 | 16% | 80 | 87 |
| 4.3.2.4 | Fabricate & test 602-720 GHz SIS Mixer Detector Modules | 0 | 0 | 18 | 44 | 302 | 558 | 78% | 1,532 | 1,656 |
| 4.3.3.1 | Design, Fab, and Test 275-370 GHz Mixer Design | 0 | 0 | 48 | 58 | 575 | 444 | 52% | 1,549 | 1,651 |
| 4.3.3.3 | Fabricate 275-370 GHz mixer blocks | 0 | 0 | 0 | 10 | 39 | 7 | 16% | 53 | 58 |
| 4.3.3.4 | Fabricate & test 275-370 GHz SIS Mixer Detector Modules | 0 | 0 | 18 | 44 | 302 | 558 | 52% | 1,308 | 1,420 |
| 4.3.4.1 | Design, Fab, and Test 89-116 GHz Mixer Design | 0 | 0 | 48 | 58 | 575 | 694 | 52% | 1,929 | 2,098 |
| 4.3.4.3 | Fabricate 89-116 GHz mixer blocks | 0 | 0 | 0 | 10 | 39 | 7 | 16% | 53 | 60 |
| 4.3.4.4 | Fabricate 89-116 GHz SIS Mixer Detector Modules | 0 | 0 | 18 | 44 | 302 | 558 | 52% | 1,308 | 1,468 |
| 4.3.5.1 | Design, Fab, and Test 163-211 GHz Mixer Design | 0 | 0 | 48 | 58 | 575 | 444 | 52% | 1,549 | 1,731 |
| 4.3.5.3 | Fabricate 163-211 GHz Mixer Blocks | 0 | 0 | 0 | 10 | 39 | 7 | 16% | 53 | 61 |
| 4.3.5.4 | Fabricate & test 163-211 GHz SIS Mixer Detector Modules | 0 | 0 | 18 | 44 | 302 | 558 | 52% | 1,308 | 1,499 |
| 4.3.6.1 | Design, Fab, and Test 385-500 GHz Mixer Design | 0 | 0 | 48 | 58 | 575 | 434 | 52% | 1,533 | 1,721 |
| 4.3.6.3 | Fabricate 385-500 GHz mixer blocks | 0 | 0 | 0 | 10 | 39 | 14 | 16% | 62 | 72 |
| 4.3.6.4 | Fabricate & Test 385-500 GHz SIS Mixer Detector Modules | 0 | 0 | 18 | 44 | 302 | 558 | 52% | 1,308 | 1,530 |
| 4.3.7.1 | Design, Fab, and Test 125-163 GHz Mixer Design | 0 | 0 | 48 | 58 | 575 | 444 | 52% | 1,549 | 1,783 |
| 4.3.7.3 | Fabricate 125-163 GHz mixer blocks | 0 | 0 | 0 | 10 | 39 | 7 | 16% | 53 | 63 |
| 4.3.7.4 | Fabricate & Test 125-163 GHz SIS Mixer Detector Modules | 0 | 0 | 18 | 44 | 302 | 578 | 34% | 1,180 | 1,405 |
| 4.3.8.1 | Build SIS Fabrication Equipment | 0 | 0 | 6 | 24 | 137 | 846 | 14% | 1,121 | 1,178 |
| 4.3.8.2 | Build SIS Test Dewar & Rack #1 | 0 | 0 | 6 | 24 | 137 | 303 | 14% | 502 | 527 |
| 4.3.8.3 | Build SIS Test Dewar & Rack #2 | 0 | 0 | 6 | 24 | 137 | 303 | 14% | 502 | 529 |
| 4.3.8.4 | Build SIS Test Dewar & Rack #3 | 0 | 0 | 6 | 24 | 137 | 303 | 14% | 502 | 530 |
| 4.3.8.5 | Build SIS Test Dewar & Rack #4 | 0 | 0 | 6 | 24 | 137 | 303 | 14% | 502 | 530 |
| 4.3.8.6 | Build Wafer Evaluation Test Sets | 0 | 0 | 6 | 6 | 67 | 79 | 18% | 172 | 181 |
| 4.3.8.7.1 | General SIS Test Equipment | 0 | 0 | 0 | 0 | 0 | 126 | 5% | 132 | 141 |
| 4.3.8.7.2 | Equip Network Analyzer to 330 GHz | 0 | 0 | 7 | 0 | 51 | 594 | 15% | 742 | 796 |

# Millimeter Array Construction: Project Totals

US Reference Project

| WBS | Task Name | Scientists Work-months | Programmers Work-months | Engineers Work-months | Technicians Work-months | Personnel 1999 $K | Materials & Supplies 1999 $K | Contingency | Total Cost 1999 $K | Inflated Cost $K |
|---|---|---|---|---|---|---|---|---|---|---|
| 4.3.8.7.3 | Near-Field Antenna Test Equipment | 0 | 0 | 15 | 12 | 156 | 89 | 15% | 281 | 302 |
| 4.3.8.8 | Build 211-275 GHz Test Plates | 0 | 0 | 6 | 6 | 67 | 240 | 14% | 350 | 368 |
| 4.3.8.9 | Build 602-720 GHz Test Plates | 0 | 0 | 6 | 6 | 67 | 260 | 14% | 373 | 392 |
| 4.3.8.10 | Build 275-370 GHz Test Plates | 0 | 0 | 6 | 6 | 67 | 240 | 14% | 350 | 377 |
| 4.3.8.11 | Build 89-116 GHz Test Plates | 0 | 0 | 6 | 6 | 67 | 220 | 14% | 327 | 361 |
| 4.3.8.12 | Build 163-211 GHz Test Plates | 0 | 0 | 6 | 6 | 67 | 240 | 14% | 350 | 386 |
| 4.3.8.13 | Build 385-500 GHz Test Plates | 0 | 0 | 6 | 6 | 67 | 260 | 14% | 373 | 422 |
| 4.3.8.14 | Build 125-163 GHz Test Plates | 0 | 0 | 6 | 6 | 67 | 240 | 14% | 350 | 406 |
| 4.3.9.1 | Obtain and evaluate InP IF amplifier wafers | 0 | 0 | 6 | 12 | 90 | 200 | 10% | 319 | 336 |
| 4.3.9.2 | Build IF amplifiers | 0 | 0 | 42 | 196 | 1,069 | 608 | 10% | 1,845 | 2,092 |
| 4.4.1 | Contract for HFET wafer | 0 | 0 | 2 | 0 | 15 | 100 | 24% | 142 | 149 |
| 4.4.2 | Receive and evaluate InP LNA wafer | 0 | 0 | 3 | 6 | 45 | 12 | 16% | 66 | 70 |
| 4.4.3.1 | Build 31-45 GHz HFET Detector Modules | 0 | 0 | 12 | 31 | 208 | 99 | 10% | 337 | 361 |
| 4.4.4.1 | Design 67-90 GHz amplifier | 0 | 0 | 6 | 6 | 67 | 9 | 26% | 96 | 102 |
| 4.4.4.2 | Build 67-90 GHz HFET Detector Modules | 0 | 0 | 12 | 36 | 228 | 99 | 14% | 372 | 403 |
| | | | | | | | | | | |
| 5.1 | LO Reference: Prototype Systems | 0 | 6 | 24 | 49 | 401 | 302 | 20% | 844 | 893 |
| 5.2.1 | Production test and lab equipment | 0 | 0 | 0 | 0 | 0 | 282 | 10% | 310 | 334 |
| 5.2.2 | H-maser Frequency Standard (& Rb) | 0 | 0 | 2 | 2 | 22 | 300 | 8% | 348 | 375 |
| 5.2.3 | 8 GHz PL Oscillator & Distributor | 0 | 0 | 9 | 14 | 120 | 194 | 12% | 351 | 400 |
| 5.2.4 | 10 GHz PL Oscillator & Distributor | 0 | 0 | 9 | 14 | 120 | 194 | 12% | 351 | 400 |
| 5.2.5 | 12 GHz PL Oscillator & Distributor | 0 | 0 | 9 | 14 | 120 | 194 | 12% | 351 | 400 |
| 5.2.6 | 14 GHz PL Oscillator & Distributor | 0 | 0 | 8 | 13 | 109 | 194 | 12% | 339 | 386 |
| 5.2.7 | 3.2-5.2 GHz Synthesizer | 0 | 0 | 12 | 65 | 341 | 1,824 | 16% | 2,511 | 2,853 |
| 5.2.8 | 3.2 -5.2 GHz PLO and Fringe Generator | 0 | 0 | 10 | 33 | 201 | 638 | 14% | 957 | 1,087 |
| 5.2.9 | Sampler Clock 4 GHz PL Osc & Distributor | 0 | 0 | 9 | 18 | 136 | 194 | 12% | 369 | 419 |
| 5.2.10 | LO Ref Generator | 0 | 0 | 2 | 2 | 22 | 30 | 12% | 59 | 67 |
| 5.2.11 | LO Ref Distributor - Control Bldg | 0 | 0 | 2 | 2 | 22 | 43 | 14% | 74 | 84 |
| 5.2.12 | Microwave Round-trip Phase Measurement | 0 | 0 | 16 | 23 | 206 | 547 | 49% | 1,122 | 1,267 |
| 5.2.13 | 10-15 GHz Frequency Synthesizer | 0 | 0 | 9 | 34 | 198 | 384 | 49% | 867 | 985 |
| 5.2.14 | First LO Fringe Generator | 0 | 0 | 7 | 33 | 180 | 638 | 16% | 949 | 1,077 |
| 5.2.15 | 16 GHz PL Oscillator & Distributor | 0 | 0 | 5 | 13 | 87 | 194 | 12% | 314 | 358 |
| 5.2.16 | 26 GHz PL Oscillator & Distributor | 0 | 0 | 5 | 13 | 87 | 194 | 12% | 314 | 358 |
| 5.2.17 | LO Ref Distributor - Antenna | 0 | 0 | 4 | 13 | 80 | 258 | 18% | 399 | 454 |
| 5.2.18 | VXCO Clean-up Loop | 0 | 0 | 5 | 13 | 87 | 578 | 100% | 1,329 | 1,511 |
| 5.2.19 | Power supply module | 0 | 0 | 7 | 10 | 90 | 103 | 5% | 202 | 229 |
| 5.2.20 | Bins / Racks (assemble and test) | 0 | 0 | 0 | 1 | 4 | 62 | 14% | 75 | 85 |
| 5.3.1 | LO Source Design and System Integration | 0 | 0 | 66 | 99 | 865 | 100 | 36% | 1,313 | 1,459 |
| 5.3.2.1 | 72-95 GHz LO Source Procurement & Fabrication | 0 | 0 | 5 | 34 | 169 | 544 | 24% | 884 | 947 |
| 5.3.2.2 | 72-95 GHz LO Source Assembly & Test | 0 | 0 | 6 | 7 | 71 | 12 | 24% | 102 | 110 |
| 5.3.3.1 | 102-120 GHz LO Source Procurement & Fabrication | 0 | 0 | 5 | 34 | 169 | 573 | 24% | 920 | 987 |
| 5.3.3.2 | 102-120 GHz LO Source Assembly & Test | 0 | 0 | 6 | 7 | 71 | 12 | 24% | 103 | 111 |
| 5.3.4.1 | 87-108 GHz LO Source Procurement & Fabrication | 0 | 0 | 5 | 34 | 169 | 544 | 24% | 884 | 995 |
| 5.3.4.2 | 87-108 GHz LO Source Assembly & Test | 0 | 0 | 6 | 7 | 71 | 12 | 24% | 102 | 115 |
| 5.3.5.1 | 65-86 GHz LO Source Procurement & Fabrication | 0 | 0 | 5 | 34 | 169 | 544 | 24% | 884 | 995 |
| 5.3.5.2 | 65-86 GHz LO Source Assembly & Test | 0 | 0 | 6 | 7 | 71 | 12 | 24% | 102 | 115 |
| 5.4.1 | LO Multiplier Chain Design & System Integration | 0 | 0 | 99 | 99 | 1,105 | 1,725 | 36% | 3,848 | 4,269 |
| 5.4.2.1 | 211-275 GHz Receiver LO multiplier Parts | 0 | 0 | 1 | 5 | 27 | 30 | 34% | 77 | 82 |
| 5.4.2.2 | 211-275 GHz Receiver LO Multiplier Assembly & Test | 0 | 0 | 2 | 11 | 57 | 0 | 34% | 77 | 85 |
| 5.4.2.3 | 275-370 GHz LO integrate source & multiplier | 0 | 0 | 6 | 16 | 106 | 19 | 34% | 167 | 187 |
| 5.4.3.1 | 602-720 GHz Receiver LO multiplier Parts | 0 | 0 | 2 | 8 | 46 | 61 | 34% | 143 | 154 |
| 5.4.3.2 | 602-720 GHz Receiver LO multiplier Assembly & Test | 0 | 0 | 4 | 22 | 115 | 0 | 34% | 154 | 171 |

# Millimeter Array Construction: Project Totals

US Reference Project

| WBS | Task Name | Scientists Work-months | Programmers Work-months | Engineers Work-months | Technicians Work-months | Personnel 1999 $K | Materials & Supplies 1999 $K | Contingency | Total Cost 1999 $K | Inflated Cost $K |
|---|---|---|---|---|---|---|---|---|---|---|
| 5.4.3.3 | 602-720 GHz LO integrate source & multiplier | 0 | 0 | 8 | 24 | 152 | 38 | 34% | 254 | 284 |
| 5.4.4.1 | 275-370 GHz Receiver LO multiplier Parts | 0 | 0 | 2 | 8 | 46 | 61 | 34% | 143 | 154 |
| 5.4.4.2 | 275-370 GHz Receiver LO multiplier Assembly & Test | 0 | 0 | 4 | 22 | 115 | 0 | 34% | 154 | 173 |
| 5.4.4.3 | 275-370 GHz LO integrate source & multiplier | 0 | 0 | 8 | 24 | 152 | 38 | 34% | 254 | 284 |
| 5.4.5.1 | 163-211 GHz Receiver LO multiplier Parts | 0 | 0 | 1 | 5 | 27 | 30 | 34% | 77 | 85 |
| 5.4.5.2 | 163-211 GHz Receiver LO multiplier Assembly & Test | 0 | 0 | 2 | 11 | 57 | 0 | 34% | 77 | 88 |
| 5.4.5.3 | 163-211 GHz LO integrate source & multiplier | 0 | 0 | 6 | 16 | 106 | 19 | 34% | 167 | 187 |
| 5.4.6.1 | 385-500 GHz Receiver LO multiplier Parts | 0 | 0 | 2 | 8 | 46 | 61 | 34% | 143 | 158 |
| 5.4.6.2 | 385-500 GHz Receiver LO multiplier Assembly & Test | 0 | 0 | 2 | 11 | 57 | 0 | 34% | 77 | 88 |
| 5.4.6.3 | 385-500 GHz LO integrate source & multiplier | 0 | 0 | 8 | 24 | 152 | 38 | 34% | 254 | 291 |
| 5.4.7.1 | 125-163 GHz Receiver LO multiplier Parts | 0 | 0 | 1 | 5 | 27 | 30 | 34% | 77 | 85 |
| 5.4.7.2 | 125-163 GHz Receiver LO multiplier Assembly & Test | 0 | 0 | 2 | 11 | 57 | 0 | 34% | 77 | 89 |
| 5.4.7.3 | 125-163 GHz LO integrate source & multiplier | 0 | 0 | 6 | 16 | 106 | 19 | 34% | 167 | 196 |
| 5.4.8.1 | Design & fab 31-45 GHz receiver LO coupling | 0 | 0 | 8 | 12 | 105 | 19 | 12% | 139 | 148 |
| 5.4.9 | LO Multiplier Fabrication Equipment | 0 | 0 | 0 | 0 | 0 | 181 | 11% | 200 | 211 |
| 5.4.10 | LO Multiplier Test Equipment | 0 | 0 | 3 | 0 | 22 | 394 | 11% | 461 | 489 |
| | | | | | | | | | | |
| 6.1 | IF Field Prototype for Test Interferometer of 2 antennas. | 0 | 0 | 20 | 24 | 239 | 175 | 10% | 455 | 482 |
| 6.2 | IF Construction test & lab equipment | 0 | 0 | 10 | 11 | 115 | 242 | 5% | 375 | 396 |
| 6.3 | IF Multiplexer (2/antenna) | 0 | 0 | 33 | 65 | 493 | 2,745 | 20% | 3,885 | 4,420 |
| 6.4 | IF Demultiplexer (2/antenna) | 0 | 0 | 26 | 60 | 423 | 970 | 10% | 1,532 | 1,746 |
| 6.5 | IF Matrix Switch (2/antenna) | 0 | 0 | 9 | 30 | 182 | 603 | 6% | 832 | 945 |
| 6.6 | IF Baseband Converter (8/antenna) | 0 | 0 | 32 | 63 | 478 | 2,335 | 20% | 3,375 | 3,842 |
| 6.7 | IF Power Supply module | 0 | 0 | 2 | 6 | 38 | 78 | 5% | 121 | 137 |
| 6.8 | Bins / Racks (assemble and test) | 0 | 0 | 4 | 14 | 84 | 170 | 5% | 266 | 300 |
| | | | | | | | | | | |
| 7.1 | Prototype Optical Fiber Systems | 0 | 0 | 43 | 62 | 554 | 324 | 32% | 1,159 | 1,233 |
| 7.2 | Digital IF Transmitters and Receivers | 0 | 0 | 99 | 123 | 1,198 | 3,899 | 40% | 7,136 | 8,087 |
| 7.3.1 | 16 GHZ FO LO Ref Dist Prototype | 0 | 0 | 45 | 90 | 678 | 206 | 40% | 1,238 | 1,320 |
| 7.3.2 | 16 GHz FO LO Ref Dist with Integrated R/T Phase Meas. | 0 | 0 | 84 | 144 | 1,171 | 825 | 28% | 2,556 | 2,896 |
| 7.4 | Production Test Equipment | 0 | 0 | 2 | 2 | 22 | 219 | 5% | 253 | 266 |
| 7.5 | Monitor and Control Transmitters and Receivers | 0 | 0 | 29 | 70 | 483 | 252 | 14% | 838 | 958 |
| 7.6 | Fiber Optics Power Supply Modules | 0 | 0 | 13 | 24 | 188 | 88 | 14% | 315 | 358 |
| 7.7 | Bins / Racks (assemble and test) | 0 | 0 | 25 | 46 | 361 | 106 | 14% | 533 | 610 |
| | | | | | | | | | | |
| 8.1.1 | Refine digitizer design | 0 | 0 | 3 | 6 | 45 | 5 | 30% | 65 | 69 |
| 8.1.3 | Digitizer contract materials | 0 | 0 | 3 | 3 | 33 | 928 | 30% | 1,250 | 1,346 |
| 8.1.4 | Assembly of digitizers | 0 | 0 | 1 | 23 | 97 | 0 | 26% | 122 | 132 |
| 8.1.5 | Digitizer validation and delivery | 0 | 0 | 5 | 4 | 52 | 10 | 26% | 78 | 86 |
| 8.2.1 | Prototype FIR filter testing on interferometer | 4 | 2 | 2 | 0 | 55 | 0 | 38% | 76 | 80 |
| 8.2.2 | Design & test FIR filter refinement | 1 | 1 | 3 | 3 | 47 | 5 | 32% | 68 | 72 |
| 8.2.4 | FIR filter chip & board fabrication | 0 | 0 | 1 | 1 | 11 | 884 | 32% | 1,182 | 1,264 |
| 8.2.5 | FIR filter board assembly | 0 | 0 | 2 | 12 | 61 | 10 | 26% | 90 | 98 |
| 8.2.6 | FIR filter board validation and delivery | 0 | 0 | 4 | 4 | 45 | 0 | 32% | 59 | 64 |
| 8.3.1 | Correlator boards | 0 | 12 | 30 | 8 | 320 | 31 | 26% | 443 | 465 |
| 8.4 | Correlator Chip | 0 | 0 | 18 | 8 | 162 | 2,500 | 30% | 3,460 | 3,715 |
| 8.6 | Correlator software | 0 | 36 | 0 | 0 | 215 | 9 | 20% | 268 | 289 |
| 8.5 | Correlator Racks | 0 | 0 | 3 | 6 | 45 | 31 | 20% | 91 | 96 |
| 8.7 | Prototype Correlator Production | 0 | 0 | 42 | 50 | 500 | 208 | 28% | 906 | 986 |
| 8.8.1 | First 1/4 Correlator | 0 | 0 | 36 | 36 | 402 | 399 | 28% | 1,025 | 1,139 |
| 8.8.2 | Second 1/4 Correlator | 0 | 0 | 36 | 36 | 402 | 420 | 24% | 1,019 | 1,148 |
| 8.8.3 | Third 1/4 Correlator | 0 | 0 | 18 | 18 | 201 | 399 | 24% | 744 | 849 |

# Millimeter Array Construction: Project Totals

US Reference Project

| WBS | Task Name | Scientists Work-months | Programmers Work-months | Engineers Work-months | Technicians Work-months | Personnel 1999 $K | Materials & Supplies 1999 $K | Contingency | Total Cost 1999 $K | Inflated Cost $K |
|---|---|---|---|---|---|---|---|---|---|---|
| 8.8.4 | Fourth 1/4 Correlator | 0 | 0 | 36 | 36 | 402 | 389 | 24% | 980 | 1,151 |
| 8.9 | Correlator test equipment | 0 | 0 | 0 | 0 | 0 | 49 | 5% | 51 | 54 |
| | | | | | | | | | | |
| 9 | Computing | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.1 | Control Software | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.1.1 | Test Interferometer Control and Analysis | 0 | 48 | 0 | 0 | 286 | 0 | 34% | 383 | 405 |
| 9.1.2 | MMA Correlator Software | 9 | 180 | 0 | 0 | 1,137 | 0 | 34% | 1,523 | 1,689 |
| 9.1.3 | Multi-antenna & sub-array control | 0 | 78 | 0 | 0 | 465 | 500 | 34% | 1,293 | 1,477 |
| 9.1.4 | Operators and Observers Interfaces | 0 | 72 | 0 | 0 | 429 | 30 | 34% | 615 | 675 |
| 9.1.5 | Deliver control software | 0 | 0 | 0 | 0 | 0 | 0 | 30% | 0 | 0 |
| 9.1.6 | Maintenance | 0 | 0 | 0 | 0 | 0 | 0 | 18% | 0 | 0 |
| 9.2 | Scheduling | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.2.1 | Static Scheduling System | 0 | 33 | 0 | 0 | 197 | 0 | 34% | 263 | 301 |
| 9.2.2 | Dynamic scheduling simulations | 24 | 0 | 0 | 0 | 172 | 0 | 34% | 230 | 263 |
| 9.2.3 | Dynamic scheduling prototype | 3 | 6 | 0 | 0 | 57 | 0 | 30% | 74 | 86 |
| 9.2.4 | Dynamic scheduling implementation | 18 | 36 | 0 | 0 | 343 | 0 | 39% | 477 | 572 |
| 9.3 | Proposal preparation software | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.3.1 | Proposal assistance prototype | 3 | 6 | 0 | 0 | 57 | 0 | 30% | 74 | 84 |
| 9.3.2 | Proposal assistance implementation | 9 | 24 | 0 | 0 | 207 | 0 | 30% | 270 | 320 |
| 9.3.3 | Observe program prototype | 6 | 9 | 0 | 0 | 97 | 0 | 26% | 122 | 136 |
| 9.3.4 | Observe program | 9 | 12 | 0 | 0 | 136 | 0 | 26% | 171 | 202 |
| 9.4 | Image pipeline | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.4.1 | Automated calibration & imaging heuristics | 12 | 0 | 0 | 0 | 86 | 0 | 39% | 119 | 133 |
| 9.4.2 | Prototype image pipeline | 6 | 12 | 0 | 0 | 114 | 0 | 30% | 149 | 170 |
| 9.4.3 | Parallelization studies and implementation | 0 | 24 | 0 | 0 | 143 | 55 | 34% | 265 | 303 |
| 9.4.4 | Initial image pipeline operations | 0 | 0 | 0 | 0 | 0 | 0 | 26% | 0 | 0 |
| 9.4.5 | Production image pipeline | 18 | 36 | 0 | 0 | 343 | 250 | 30% | 771 | 926 |
| 9.5 | Archiving | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.5.1 | Prototype distributed archive | 9 | 12 | 0 | 0 | 136 | 21 | 30% | 204 | 227 |
| 9.5.2 | Evaluate storage hardware | 3 | 3 | 0 | 0 | 39 | 0 | 11% | 44 | 52 |
| 9.5.3 | Production archive | 12 | 36 | 0 | 0 | 300 | 268 | 30% | 739 | 888 |
| 9.6 | Post processing | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.6.1 | Define data formats | 6 | 0 | 0 | 0 | 43 | 0 | 18% | 51 | 55 |
| 9.6.2 | Filler and format conversions | 0 | 12 | 0 | 0 | 72 | 0 | 22% | 87 | 100 |
| 9.6.3 | ALMA specific calibrations | 9 | 0 | 0 | 0 | 64 | 0 | 39% | 89 | 100 |
| 9.6.4 | MMA Post-processing begins | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.6.5 | Maintenance | 0 | 0 | 0 | 0 | 0 | 0 | 22% | 0 | 0 |
| 9.7 | Software support | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.7.1 | Tool support | 0 | 36 | 0 | 0 | 215 | 0 | 34% | 287 | 316 |
| 9.7.2 | Quality assurance | 0 | 84 | 0 | 0 | 501 | 0 | 34% | 671 | 773 |
| 9.7.3 | Chile system administration | 0 | 0 | 0 | 0 | 0 | 0 | 22% | 0 | 0 |
| | | | | | | | | | | |
| 10 | System Integration | 0 | 0 | 0 | 0 | 0 | 125 | 10% | 138 | 148 |
| 10.4 | Test Interferometer Site Preparation | 0 | 0 | 0 | 3 | 12 | 48 | 25% | 75 | 78 |
| 10.10 | Oufitting at U.S. test site | 0 | 0 | 0 | 0 | 0 | 0 | 12% | 0 | 0 |
| 10.10.4 | Antenna #1 Outfitting | 0 | 0 | 6 | 6 | 67 | 25 | 25% | 115 | 121 |
| 10.10.7 | Antenna #2 Outfitting | 0 | 0 | 6 | 6 | 67 | 25 | 25% | 115 | 124 |
| 10.10.10 | General Outfitting | 0 | 0 | 12 | 12 | 134 | 55 | 25% | 236 | 254 |
| 10.11 | Single Dish Tests | 0 | 0 | 0 | 0 | 0 | 0 | 11% | 0 | 0 |
| 10.11.1 | Ant #1 holography and surface readjustment | 2 | 1 | 2 | 2 | 43 | 0 | 25% | 53 | 56 |
| 10.11.2 | Ant #1 Antenna Evaluation | 6 | 2 | 4 | 4 | 99 | 0 | 25% | 124 | 132 |
| 10.11.6 | Ant #2 holography and surface readjustment | 2 | 1 | 2 | 2 | 43 | 0 | 25% | 53 | 57 |

# Millimeter Array Construction: Project Totals

US Reference Project

| WBS | Task Name | Scientists Work-months | Programmers Work-months | Engineers Work-months | Technicians Work-months | Personnel 1999 $K | Materials & Supplies 1999 $K | Contingency | Total Cost 1999 $K | Inflated Cost $K |
|---|---|---|---|---|---|---|---|---|---|---|
| 10.11.7 | Ant #2 Antenna Evaluation | 6 | 2 | 4 | 4 | 99 | 0 | 25% | 124 | 134 |
| 10.12 | Interferometric Tests | 0 | 0 | 0 | 0 | 0 | 0 | 11% | 0 | 0 |
| 10.12.1 | Phase/gain stability tests | 4 | 1 | 1 | 1 | 46 | 0 | 25% | 57 | 63 |
| 10.12.2 | Sensitivity verification | 2 | 1 | 1 | 0 | 28 | 0 | 25% | 34 | 38 |
| 10.12.3 | Holography with astronomical sources | 4 | 2 | 1 | 1 | 52 | 0 | 25% | 65 | 71 |
| 10.12.4 | Modifications and Retrofits | 6 | 3 | 6 | 3 | 116 | 0 | 35% | 157 | 177 |
| 10.13 | Dissassemble test system and ship to array site | 0 | 0 | 0 | 4 | 16 | 806 | 35% | 1,109 | 1,286 |
| 10.14 | On-site System Integration | 0 | 0 | 0 | 0 | 0 | 0 | 50% | 0 | 0 |
| 10.14.1 | Set up assembly and test facilities at OSF | 0 | 0 | 1 | 2 | 15 | 0 | 25% | 19 | 21 |
| 10.14.2 | Outfit antennas 3 through 36 | 0 | 0 | 0 | 0 | 0 | 50 | 25% | 63 | 73 |
| 10.14.2.1 | Wiring and plumbing | 0 | 0 | 0 | 33 | 127 | 374 | 25% | 626 | 725 |
| 10.14.2.2 | Install electronics in receiver cabin | 0 | 0 | 0 | 32 | 123 | 374 | 25% | 622 | 720 |
| 10.14.2.3 | Check out completed antenna at OSF | 9 | 0 | 32 | 32 | 414 | 0 | 25% | 518 | 600 |
| 10.14.2.4 | Install antenna at array site. | 0 | 0 | 0 | 36 | 138 | 0 | 25% | 173 | 201 |
| 10.14.3 | Refurbish antennas 1 and 2 | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.14.3.1 | Re-install electronics and upgrade as needed | 0 | 0 | 0 | 1 | 4 | 0 | 25% | 5 | 6 |
| 10.14.3.2 | Check out at OSF | 1 | 0 | 2 | 2 | 26 | 0 | 25% | 32 | 38 |
| 10.14.3.3 | Install antenna at array site | 0 | 0 | 0 | 2 | 8 | 0 | 25% | 10 | 11 |
| 10.14.4 | Install central building electronics | 0 | 0 | 3 | 1 | 24 | 0 | 25% | 30 | 34 |
| 10.14.5 | Support debugging and repair | 0 | 0 | 12 | 24 | 181 | 0 | 25% | 226 | 252 |
| 10.20 | Prototype Testing Support | 0 | 0 | 3 | 3 | 33 | 30 | 10% | 70 | 77 |
| | | 42 | 13 | 98 | 209 | 1915 | 1912 | | | |
| 11.1.1 | Completion of 183 GHz Water Vapor Radiometer | 0 | 0 | 1 | 0 | 7 | 0 | 11% | 8 | 8 |
| 11.1.2 | Demonstrate 183 GHz Water Vapor Radiometer | 0 | 0 | 0 | 12 | 47 | 20 | 12% | 75 | 79 |
| 11.1.3 | Refinement of 183 GHz Water Vapor Radiometer | 0 | 0 | 3 | 3 | 33 | 0 | 16% | 39 | 42 |
| 11.1.4 | Release WVR for manufacture | 0 | 0 | 0 | 0 | 0 | 300 | 10% | 330 | 353 |
| 11.2.1.1 | Contract Phase Monitor Radiometer Subassembly | 0 | 0 | 0 | 0 | 0 | 300 | 10% | 330 | 358 |
| 11.2.1.2 | WVR Spectrometer | 0 | 0 | 0 | 1 | 4 | 292 | 10% | 325 | 364 |
| 11.2.1.3 | WVR Feed, Window, Lens, Instrumentation | 0 | 0 | 0 | 0 | 0 | 200 | 10% | 220 | 239 |
| 11.2.1.4 | Monitor and Control WVR Interface | 0 | 0 | 0 | 0 | 0 | 15 | 14% | 17 | 18 |
| 11.2.3 | Deliver Production Radiometers | 0 | 0 | 0 | 12 | 47 | 20 | 9% | 73 | 81 |
| 11.2.4 | Integration of WVR into Receiver Package | 0 | 0 | 0 | 24 | 94 | 0 | 7% | 100 | 113 |
| 11.2.5 | Verification on Site of WVR | 0 | 3 | 0 | 6 | 41 | 0 | 9% | 45 | 51 |
| 11.3.1 | Dual-Load Amp. Calibration Device Design Refinement | 0 | 0 | 9 | 0 | 65 | 0 | 7% | 70 | 74 |
| 11.3.2 | Release Dual-Load Amp Cal for Mftr | 0 | 0 | 0 | 0 | 0 | 0 | 8% | 0 | 0 |
| 11.3.3 | Contract Subassembly Dual-Load Amp Cal | 0 | 0 | 0 | 0 | 0 | 0 | 7% | 0 | 0 |
| 11.3.3.1 | Dual-Load AmpCal Subassy Machining | 0 | 0 | 0 | 2 | 8 | 51 | 7% | 63 | 68 |
| 11.3.3.2 | Load Fabrication for Dual Load Amp Cal | 0 | 0 | 0 | 8 | 31 | 51 | 7% | 88 | 95 |
| 11.3.3.3 | Dual Load Amplitude Calibration Device Motors, Servo | 0 | 0 | 0 | 8 | 31 | 51 | 7% | 88 | 95 |
| 11.3.3.4 | M/C Interface for Dual Load Amp Cal Device | 0 | 0 | 0 | 11 | 43 | 76 | 7% | 127 | 138 |
| 11.3.4 | Assembly and Test of Dual Load Amplitude Calibration | 0 | 0 | 0 | 4 | 16 | 0 | 7% | 17 | 18 |
| 11.3.5 | Integration of AmpCal on Production Antennas | 0 | 0 | 0 | 12 | 47 | 0 | 7% | 50 | 59 |
| 11.4 | Imaging Studies and Project Support | 48 | 0 | 0 | 0 | 343 | 0 | 5% | 360 | 379 |
| 11.5 | Imaging Algorithm Development | 48 | 0 | 0 | 0 | 343 | 0 | 7% | 367 | 401 |
| | | | | | | | | | | |
| | Totals | 730 | 850 | 2,735 | 5,207 | 50,442 | 224,699 | | 342,590 | 388,278 |

# Millimeter Array Construction: 2001

US Reference Project

| WBS | Task Name | Scientists Work-months | Programmers Work-months | Engineers Work-months | Technicians Work-months | Personnel 1999 $K | Materials & Supplies 1999 $K | Contingency | Total Cost 1999 $K | Inflated Cost 2001 $K |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.1 | Project Management | 72 | 0 | 0 | 24 | 608 | 0 | 15% | 700 | 735 |
| 1.1.1 | Management, Planning, and Oversight | 0 | 0 | 0 | 0 | 0 | 496 | 15% | 571 | 600 |
| 1.1.2 | Business Operations | 0 | 0 | 0 | 0 | 0 | 40 | 15% | 46 | 48 |
| 1.1.3 | Chilean Operations | 0 | 0 | 0 | 0 | 0 | 55 | 15% | 63 | 66 |
| 1.1.4 | Safety and Health | 0 | 0 | 0 | 0 | 0 | 0 | 15% | 0 | 0 |
| 1.1.5 | Personnel | 0 | 0 | 0 | 0 | 0 | 0 | 15% | 0 | 0 |
| 1.1.6 | Project Science Office | 0 | 0 | 0 | 0 | 0 | 0 | 15% | 0 | 0 |
| 1.1.7 | AUI Management | 0 | 0 | 0 | 0 | 0 | 350 | 15% | 402 | 423 |
| 1.2 | Engineering | 0 | 0 | 24 | 12 | 221 | 20 | 15% | 277 | 291 |
| 1.2.1 | System Engineering--Phase II | 0 | 0 | 0 | 0 | 0 | 0 | 15% | 0 | 0 |
| 1.2.2 | Documentation System | 0 | 0 | 0 | 0 | 0 | 0 | 15% | 0 | 0 |
| 1.2.3 | Production Engineering | 0 | 0 | 0 | 0 | 0 | 0 | 15% | 0 | 0 |
| 1.3 | US Facilities | 0 | 0 | 0 | 0 | 0 | 0 | 15% | 0 | 0 |
| 1.3.1 | CDL Permanent Facilities | 0 | 0 | 0 | 0 | 0 | 600 | 0% | 600 | 600 |
| 1.3.2 | Manufacturing Facilities | 0 | 0 | 0 | 0 | 0 | 115 | 10% | 127 | 133 |
| 1.3.3 | Common Infrastructure | 0 | 0 | 0 | 0 | 0 | 200 | 15% | 230 | 242 |
| | | | | | | | | | | |
| 2 | Site Development | 0 | 0 | 12 | 0 | 87 | 50 | 5% | 144 | 151 |
| 2.2 | Maintain Mining claims | 0 | 0 | 0 | 0 | 0 | 25 | 5% | 26 | 28 |
| 2.3 | Contract A&E Studies | 0 | 0 | 0 | 0 | 0 | 938 | 20% | 1,126 | 1,183 |
| 2.5.3 | Contract Array Site Civil Works | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 2.6.3 | Contract OSF Civil Works | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 2.7.3 | Contract Civil Works | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 2.8.1 | Equip Array Site | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 2.8.2 | Equip Operations Support Facility | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| | | | | | | | | | | |
| 3.1 | Antenna Engineering Support | 0 | 0 | 48 | 0 | 348 | 0 | 14% | 397 | 417 |
| 3.8.10 | Sign Transporter Contract | 0 | 0 | 0 | 0 | 0 | 790 | 20% | 948 | 996 |
| 3.8.30 | Accept Transporter #2 at OSF | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 3.8.35 | Contract for Transporter #1 Move to site | 0 | 0 | 0 | 0 | 0 | 0 | 12% | 0 | 0 |
| 3.15 | Procurement of Antenna 2 | 0 | 0 | 0 | 0 | 0 | 3,002 | 27% | 3,813 | 4,006 |
| 3.20 | Sign Contract for Production Antennas | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 3.21 | Antenna Contract Supervision | 0 | 0 | 0 | 0 | 0 | 0 | 12% | 0 | 0 |
| 3.23 | Accept Antenna #3 at OSF | 0 | 0 | 0 | 0 | 0 | 0 | 27% | 0 | 0 |
| 3.25, 3.27, 3.2 | Accept Antennas #4 through #36 | 0 | 0 | 0 | 0 | 0 | 0 | 27% | 0 | 0 |
| | | | | | | | | | | |
| 4.1.1.2 | Fabricate PPRC | 0 | 0 | 3 | 8 | 53 | 69 | 28% | 156 | 164 |
| 4.1.1.3 | Test PPRC | 0 | 3 | 3 | 3 | 51 | 10 | 5% | 64 | 68 |
| 4.1.2.1 | PPR Dewar Design | 0 | 0 | 4 | 4 | 45 | 0 | 17% | 52 | 55 |
| 4.1.2.2 | PPR Dewar Fabrication and Vacuum Testing | 0 | 0 | 1 | 6 | 31 | 8 | 40% | 54 | 57 |
| 4.1.2.3 | PPR Vacuum Windows and IR Filters | 0 | 0 | 2 | 2 | 22 | 12 | 20% | 41 | 43 |
| 4.1.2.4 | PPR Cryogenics/Dewar Assembly and Testing | 0 | 2 | 2 | 3 | 38 | 18 | 13% | 63 | 67 |
| 4.1.3.1 | PPR Control-Monitoring and Bias Electronics Design | 0 | 0 | 6 | 6 | 67 | 0 | 21% | 81 | 85 |
| 4.1.3.2 | PPR Control-Monitor and Bias Electronics Construction | 0 | 0 | 2 | 5 | 34 | 22 | 44% | 81 | 85 |
| 4.1.4.1 | Insert Mechanical-Thermal Design, Bands <275 GHz (Waveguid | 0 | 0 | 6 | 0 | 44 | 0 | 48% | 64 | 68 |
| 4.1.4.2 | Insert Component Fabrication for Bands <275 GHz | 0 | 0 | 1 | 8 | 38 | 37 | 56% | 118 | 124 |
| 4.1.4.3 | Insert Mechanical-Thermal Design for Bands >275 GHz (Quasi o | 0 | 0 | 6 | 0 | 44 | 0 | 48% | 64 | 68 |
| 4.1.4.4 | Insert Component Fabrication for Bands >275 Ghz | 0 | 0 | 1 | 6 | 31 | 13 | 56% | 67 | 71 |
| 4.1.4.8 | PPR Insert Assembly (3 Bands) | 0 | 0 | 0 | 3 | 12 | 5 | 44% | 24 | 25 |
| 4.1.4.9 | PPR Insert Testing (3 Bands) | 0 | 0 | 2 | 2 | 22 | 0 | 16% | 26 | 27 |
| 4.1.5.1 | PPR Vacuum System Assembly | 0 | 0 | 1 | 1 | 11 | 26 | 8% | 40 | 42 |
| 4.1.7.1 | PPR Post IF System Design | 0 | 0 | 1 | 1 | 11 | 0 | 22% | 14 | 14 |

# Millimeter Array Construction: 2001

US Reference Project

| WBS | Task Name | Scientists Work-months | Programmers Work-months | Engineers Work-months | Technicians Work-months | Personnel 1999 $K | Materials & Supplies 1999 $K | Contingency | Total Cost 1999 $K | Inflated Cost 2001 $K |
|---|---|---|---|---|---|---|---|---|---|---|
| 4.1.7.2 | PPR Post IF System Construction and Testing | 0 | 0 | 2 | 2 | 22 | 32 | 24% | 67 | 71 |
| 4.1.8.1 | PPR Frame Design | 0 | 0 | 3 | 2 | 30 | 0 | 16% | 34 | 36 |
| 4.1.8.2 | PPR Frame Fabrication | 0 | 0 | 0 | 5 | 20 | 18 | 30% | 49 | 51 |
| 4.1.9.1 | Prototype Production Receiver Integration | 0 | 0 | 3 | 4 | 37 | 10 | 14% | 54 | 57 |
| 4.1.9.2 | PPR Testing and Evaluation | 0 | 2 | 3 | 4 | 49 | 38 | 36% | 119 | 125 |
| 4.1.10.1 | Design and build Prototype and Production Receiver Test Set | 0 | 3 | 6 | 12 | 108 | 444 | 36% | 751 | 789 |
| 4.1.10.2 | Design and Fabricate Receiver Insert Test Set | 0 | 4 | 4 | 8 | 84 | 213 | 11% | 330 | 346 |
| 4.1.10.3 | General Test Equipment | 0 | 0 | 1 | 1 | 11 | 360 | 13% | 419 | 441 |
| 4.2.1 | MMA Receiver (MMA Rx) Design Refinement | 0 | 0 | 0 | 0 | 0 | 0 | 28% | 0 | 0 |
| 4.2.2 | MMA Receiver (MMA Rx) Documentation | 0 | 0 | 2 | 4 | 30 | 5 | 18% | 41 | 44 |
| 4.2.4.1 | MMA Rx Dewar Fabrication | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.2.4.2 | MMA Rx Cryogenics Fabrication | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 4.2.4.3 | Vacuum Windows and IR Filters Fabrication | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.2.4.4 | Receiver Insert Fabrication | 0 | 0 | 0 | 0 | 0 | 0 | 22% | 0 | 0 |
| 4.2.4.5 | MMA Receiver Frame Fabrication and assembly | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.2.4.6 | Vacuum System Fabrication and testing. | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.2.4.7 | Bias and Control-Monitoring Electronics Construction | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.2.4.9 | Assemble Receiver Inserts and Test | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 4.2.4.10 | Assemble MMA Rx IF System | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.2.6.1 | Integrate Test & Commission MMA Receivers | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.5.1 | Construct and test Cryo system for 2nd Evaluation Receiver | 0 | 0 | 7 | 11 | 94 | 69 | 16% | 189 | 198 |
| 4.5.2 | Fabrication and assembly of 2nd Evaluation Receiver. | 0 | 3 | 6 | 50 | 256 | 292 | 16% | 636 | 668 |
| 4.5.3 | Test and Commission 2nd Evaluation Receiver | 0 | 0 | 3 | 3 | 33 | 0 | 5% | 35 | 37 |
| 4.3.1.1 | Design, Fab, and Test 211-275 GHz Mixer Design | 0 | 0 | 6 | 7 | 69 | 96 | 52% | 251 | 264 |
| 4.3.1.3 | Fabricate 211-275 GHz mixer blocks | 0 | 0 | 0 | 5 | 20 | 5 | 16% | 28 | 29 |
| 4.3.1.4 | Fabricate & test 211-275 GHz SIS Mixer Detector Modules | 0 | 0 | 9 | 22 | 151 | 293 | 52% | 675 | 709 |
| 4.3.2.1 | Design, Fab, and Test 602-720 GHz Mixer Design | 0 | 0 | 24 | 38 | 322 | 632 | 52% | 1,451 | 1,524 |
| 4.3.2.3 | Fabricate 602-720 GHz mixer blocks | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.3.2.4 | Fabricate & test 602-720 GHz SIS Mixer Detector Modules | 0 | 0 | 0 | 0 | 0 | 150 | 78% | 267 | 281 |
| 4.3.3.1 | Design, Fab, and Test 275-370 GHz Mixer Design | 0 | 0 | 24 | 29 | 287 | 117 | 52% | 615 | 646 |
| 4.3.3.3 | Fabricate 275-370 GHz mixer blocks | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.3.3.4 | Fabricate & test 275-370 GHz SIS Mixer Detector Modules | 0 | 0 | 0 | 0 | 0 | 0 | 52% | 0 | 0 |
| 4.3.4.1 | Design, Fab, and Test 89-116 GHz Mixer Design | 0 | 0 | 0 | 0 | 0 | 0 | 52% | 0 | 0 |
| 4.3.4.3 | Fabricate 89-116 GHz mixer blocks | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.3.4.4 | Fabricate 89-116 GHz SIS Mixer Detector Modules | 0 | 0 | 0 | 0 | 0 | 0 | 52% | 0 | 0 |
| 4.3.5.1 | Design, Fab, and Test 163-211 GHz Mixer Design | 0 | 0 | 0 | 0 | 0 | 0 | 52% | 0 | 0 |
| 4.3.5.3 | Fabricate 163-211 GHz Mixer Blocks | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.3.5.4 | Fabricate & test 163-211 GHz SIS Mixer Detector Modules | 0 | 0 | 0 | 0 | 0 | 0 | 52% | 0 | 0 |
| 4.3.6.1 | Design, Fab, and Test 385-500 GHz Mixer Design | 0 | 0 | 0 | 0 | 0 | 0 | 52% | 0 | 0 |
| 4.3.6.3 | Fabricate 385-500 GHz mixer blocks | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.3.6.4 | Fabricate & Test 385-500 GHz SIS Mixer Detector Modules | 0 | 0 | 0 | 0 | 0 | 0 | 52% | 0 | 0 |
| 4.3.7.1 | Design, Fab, and Test 125-163 GHz Mixer Design | 0 | 0 | 0 | 0 | 0 | 0 | 52% | 0 | 0 |
| 4.3.7.3 | Fabricate 125-163 GHz mixer blocks | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.3.7.4 | Fabricate & Test 125-163 GHz SIS Mixer Detector Modules | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 4.3.8.1 | Build SIS Fabrication Equipment | 0 | 0 | 6 | 24 | 137 | 846 | 14% | 1,121 | 1,178 |
| 4.3.8.2 | Build SIS Test Dewar & Rack #1 | 0 | 0 | 6 | 24 | 137 | 303 | 14% | 502 | 527 |
| 4.3.8.3 | Build SIS Test Dewar & Rack #2 | 0 | 0 | 4 | 14 | 84 | 303 | 14% | 441 | 463 |
| 4.3.8.4 | Build SIS Test Dewar & Rack #3 | 0 | 0 | 2 | 10 | 54 | 303 | 14% | 406 | 427 |
| 4.3.8.5 | Build SIS Test Dewar & Rack #4 | 0 | 0 | 2 | 4 | 30 | 303 | 14% | 380 | 399 |
| 4.3.8.6 | Build Wafer Evaluation Test Sets | 0 | 0 | 6 | 6 | 67 | 79 | 18% | 172 | 181 |
| 4.3.8.7.1 | General SIS Test Equipment | 0 | 0 | 0 | 0 | 0 | 63 | 5% | 66 | 69 |
| 4.3.8.7.2 | Equip Network Analyzer to 330 GHz | 0 | 0 | 3 | 0 | 22 | 326 | 15% | 400 | 420 |

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US Reference Project

| WBS | Task Name | Scientists Work-months | Programmers Work-months | Engineers Work-months | Technicians Work-months | Personnel 1999 $K | Materials & Supplies 1999 $K | Contingency | Total Cost 1999 $K | Inflated Cost 2001 $K |
|---|---|---|---|---|---|---|---|---|---|---|
| 4.3.8.7.3 | Near-Field Antenna Test Equipment | 0 | 0 | 3 | 0 | 22 | 30 | 15% | 59 | 62 |
| 4.3.8.8 | Build 211-275 GHz Test Plates | 0 | 0 | 6 | 6 | 67 | 240 | 14% | 350 | 368 |
| 4.3.8.9 | Build 602-720 GHz Test Plates | 0 | 0 | 6 | 6 | 67 | 260 | 14% | 373 | 392 |
| 4.3.8.10 | Build 275-370 GHz Test Plates | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.3.8.11 | Build 89-116 GHz Test Plates | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.3.8.12 | Build 163-211 GHz Test Plates | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.3.8.13 | Build 385-500 GHz Test Plates | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.3.8.14 | Build 125-163 GHz Test Plates | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.3.9.1 | Obtain and evaluate InP IF amplifier wafers | 0 | 0 | 6 | 12 | 90 | 200 | 10% | 319 | 336 |
| 4.3.9.2 | Build IF amplifiers | 0 | 0 | 6 | 12 | 90 | 52 | 10% | 157 | 165 |
| 4.4.1 | Contract for HFET wafer | 0 | 0 | 2 | 0 | 15 | 100 | 24% | 142 | 149 |
| 4.4.2 | Receive and evaluate InP LNA wafer | 0 | 0 | 3 | 6 | 45 | 12 | 16% | 66 | 70 |
| 4.4.3.1 | Build 31-45 GHz HFET Detector Modules | 0 | 0 | 3 | 8 | 53 | 25 | 10% | 85 | 90 |
| 4.4.4.1 | Design 67-90 GHz amplifier | 0 | 0 | 2 | 2 | 22 | 7 | 26% | 37 | 39 |
| 4.4.4.2 | Build 67-90 GHz HFET Detector Modules | 0 | 0 | 0 | 0 | 0 | 25 | 14% | 28 | 29 |
| | | | | | | | | | | |
| 5.1 | LO Reference: Prototype Systems | 0 | 6 | 12 | 24 | 216 | 302 | 20% | 622 | 654 |
| 5.2.1 | Production test and lab equipment | 0 | 0 | 0 | 0 | 0 | 0 | 10% | 0 | 0 |
| 5.2.2 | H-maser Frequency Standard (& Rb) | 0 | 0 | 0 | 0 | 0 | 0 | 8% | 0 | 0 |
| 5.2.3 | 8 GHz PL Oscillator & Distributor | 0 | 0 | 1 | 1 | 11 | 0 | 12% | 12 | 13 |
| 5.2.4 | 10 GHz PL Oscillator & Distributor | 0 | 0 | 1 | 1 | 11 | 0 | 12% | 12 | 13 |
| 5.2.5 | 12 GHz PL Oscillator & Distributor | 0 | 0 | 1 | 1 | 11 | 0 | 12% | 12 | 13 |
| 5.2.6 | 14 GHz PL Oscillator & Distributor | 0 | 0 | 0 | 0 | 0 | 0 | 12% | 0 | 0 |
| 5.2.7 | 3.2-5.2 GHz Synthesizer | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 5.2.8 | 3.2 -5.2 GHz PLO and Fringe Generator | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 5.2.9 | Sampler Clock 4 GHz PL Osc & Distributor | 0 | 0 | 1 | 1 | 11 | 0 | 12% | 12 | 13 |
| 5.2.10 | LO Ref Generator | 0 | 0 | 0 | 0 | 0 | 0 | 12% | 0 | 0 |
| 5.2.11 | LO Ref Distributor - Control Bldg | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 5.2.12 | Microwave Round-trip Phase Measurement | 0 | 0 | 3 | 3 | 33 | 0 | 49% | 50 | 52 |
| 5.2.13 | 10-15 GHz Frequency Synthesizer | 0 | 0 | 0 | 0 | 0 | 0 | 49% | 0 | 0 |
| 5.2.14 | First LO Fringe Generator | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 5.2.15 | 16 GHz PL Oscillator & Distributor | 0 | 0 | 0 | 0 | 0 | 0 | 12% | 0 | 0 |
| 5.2.16 | 26 GHz PL Oscillator & Distributor | 0 | 0 | 0 | 0 | 0 | 0 | 12% | 0 | 0 |
| 5.2.17 | LO Ref Distributor - Antenna | 0 | 0 | 0 | 0 | 0 | 0 | 18% | 0 | 0 |
| 5.2.18 | VXCO Clean-up Loop | 0 | 0 | 0 | 0 | 0 | 0 | 100% | 0 | 0 |
| 5.2.19 | Power supply module | 0 | 0 | 1 | 1 | 11 | 0 | 5% | 12 | 12 |
| 5.2.20 | Bins / Racks (assemble and test) | 0 | 0 | 0 | 0 | 0 | 1 | 14% | 1 | 1 |
| 5.3.1 | LO Source Design and System Integration | 0 | 0 | 12 | 18 | 157 | 20 | 36% | 241 | 253 |
| 5.3.2.1 | 72-95 GHz LO Source Procurement & Fabrication | 0 | 0 | 2 | 12 | 61 | 229 | 24% | 360 | 378 |
| 5.3.2.2 | 72-95 GHz LO Source Assembly & Test | 0 | 0 | 3 | 3 | 33 | 5 | 24% | 48 | 50 |
| 5.3.3.1 | 102-120 GHz LO Source Procurement & Fabrication | 0 | 0 | 2 | 12 | 61 | 229 | 24% | 360 | 378 |
| 5.3.3.2 | 102-120 GHz LO Source Assembly & Test | 0 | 0 | 3 | 3 | 33 | 5 | 24% | 48 | 50 |
| 5.3.4.1 | 87-108 GHz LO Source Procurement & Fabrication | 0 | 0 | 0 | 0 | 0 | 0 | 24% | 0 | 0 |
| 5.3.4.2 | 87-108 GHz LO Source Assembly & Test | 0 | 0 | 0 | 0 | 0 | 0 | 24% | 0 | 0 |
| 5.3.5.1 | 65-86 GHz LO Source Procurement & Fabrication | 0 | 0 | 0 | 0 | 0 | 0 | 24% | 0 | 0 |
| 5.3.5.2 | 65-86 GHz LO Source Assembly & Test | 0 | 0 | 0 | 0 | 0 | 0 | 24% | 0 | 0 |
| 5.4.1 | LO Multiplier Chain Design & System Integration | 0 | 0 | 18 | 18 | 201 | 335 | 36% | 729 | 766 |
| 5.4.2.1 | 211-275 GHz Receiver LO multiplier Parts | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.2.2 | 211-275 GHz Receiver LO Multiplier Assembly & Test | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.2.3 | 275-370 GHz LO integrate source & multiplier | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.3.1 | 602-720 GHz Receiver LO multiplier Parts | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.3.2 | 602-720 GHz Receiver LO multiplier Assembly & Test | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |

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|---|---|---|---|---|---|---|---|---|---|---|
| 5.4.3.3 | 602-720 GHz LO integrate source & multiplier | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.4.1 | 275-370 GHz Receiver LO multiplier Parts | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.4.2 | 275-370 GHz Receiver LO multiplier Assembly & Test | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.4.3 | 275-370 GHz LO integrate source & multiplier | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.5.1 | 163-211 GHz Receiver LO multiplier Parts | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.5.2 | 163-211 GHz Receiver LO multiplier Assembly & Test | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.5.3 | 163-211 GHz LO integrate source & multiplier | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.6.1 | 385-500 GHz Receiver LO multiplier Parts | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.6.2 | 385-500 GHz Receiver LO multiplier Assembly & Test | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.6.3 | 385-500 GHz LO integrate source & multiplier | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.7.1 | 125-163 GHz Receiver LO multiplier Parts | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.7.2 | 125-163 GHz Receiver LO multiplier Assembly & Test | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.7.3 | 125-163 GHz LO integrate source & multiplier | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.8.1 | Design & fab 31-45 GHz receiver LO coupling | 0 | 0 | 4 | 6 | 52 | 10 | 12% | 70 | 73 |
| 5.4.9 | LO Multiplier Fabrication Equipment | 0 | 0 | 0 | 0 | 0 | 157 | 11% | 174 | 183 |
| 5.4.10 | LO Multiplier Test Equipment | 0 | 0 | 2 | 0 | 15 | 231 | 11% | 272 | 286 |
| | | | | | | | | | | |
| 6.1 | IF Field Prototype for Test Interferometer of 2 antennas. | 0 | 0 | 12 | 12 | 134 | 175 | 10% | 340 | 357 |
| 6.2 | IF Construction test & lab equipment | 0 | 0 | 6 | 6 | 67 | 242 | 5% | 324 | 341 |
| 6.3 | IF Multiplexer (2/antenna) | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 6.4 | IF Demultiplexer (2/antenna) | 0 | 0 | 0 | 0 | 0 | 0 | 10% | 0 | 0 |
| 6.5 | IF Matrix Switch (2/antenna) | 0 | 0 | 0 | 0 | 0 | 0 | 6% | 0 | 0 |
| 6.6 | IF Baseband Converter (8/antenna) | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 6.7 | IF Power Supply module | 0 | 0 | 0 | 0 | 0 | 0 | 5% | 0 | 0 |
| 6.8 | Bins / Racks (assemble and test) | 0 | 0 | 0 | 0 | 0 | 0 | 5% | 0 | 0 |
| | | | | | | | | | | |
| 7.1 | Prototype Optical Fiber Systems | 0 | 0 | 18 | 24 | 224 | 324 | 32% | 724 | 760 |
| 7.2 | Digital IF Transmitters and Receivers | 0 | 0 | 0 | 0 | 0 | 0 | 40% | 0 | 0 |
| 7.3.1 | 16 GHZ FO LO Ref Dist Prototype | 0 | 0 | 18 | 36 | 271 | 206 | 40% | 668 | 702 |
| 7.3.2 | 16 GHz FO LO Ref Dist with Integrated R/T Phase Meas. | 0 | 0 | 0 | 0 | 0 | 0 | 28% | 0 | 0 |
| 7.4 | Production Test Equipment | 0 | 0 | 2 | 2 | 22 | 219 | 5% | 253 | 266 |
| 7.5 | Monitor and Control Transmitters and Receivers | 0 | 0 | 0 | 0 | 0 | 6 | 14% | 7 | 7 |
| 7.6 | Fiber Optics Power Supply Modules | 0 | 0 | 0 | 0 | 0 | 2 | 14% | 3 | 3 |
| 7.7 | Bins / Racks (assemble and test) | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| | | | | | | | | | | |
| 8.1.1 | Refine digitizer design | 0 | 0 | 3 | 6 | 45 | 5 | 30% | 65 | 69 |
| 8.1.3 | Digitizer contract materials | 0 | 0 | 0 | 0 | 0 | 0 | 30% | 0 | 0 |
| 8.1.4 | Assembly of digitizers | 0 | 0 | 0 | 0 | 0 | 0 | 26% | 0 | 0 |
| 8.1.5 | Digitizer validation and delivery | 0 | 0 | 0 | 0 | 0 | 0 | 26% | 0 | 0 |
| 8.2.1 | Prototype FIR filter testing on interferometer | 4 | 2 | 2 | 0 | 55 | 0 | 38% | 76 | 80 |
| 8.2.2 | Design & test FIR filter refinement | 1 | 1 | 3 | 3 | 47 | 5 | 32% | 68 | 72 |
| 8.2.4 | FIR filter chip & board fabrication | 0 | 0 | 1 | 1 | 11 | 234 | 32% | 324 | 340 |
| 8.2.5 | FIR filter board assembly | 0 | 0 | 0 | 0 | 0 | 0 | 26% | 0 | 0 |
| 8.2.6 | FIR filter board validation and delivery | 0 | 0 | 0 | 0 | 0 | 0 | 32% | 0 | 0 |
| 8.3.1 | Correlator boards | 0 | 12 | 30 | 8 | 320 | 31 | 26% | 443 | 465 |
| 8.4 | Correlator Chip | 0 | 0 | 6 | 4 | 59 | 275 | 30% | 434 | 456 |
| 8.6 | Correlator software | 0 | 12 | 0 | 0 | 72 | 2 | 20% | 88 | 93 |
| 8.5 | Correlator Racks | 0 | 0 | 3 | 6 | 45 | 31 | 20% | 91 | 96 |
| 8.7 | Prototype Correlator Production | 0 | 0 | 0 | 0 | 0 | 0 | 28% | 0 | 0 |
| 8.8.1 | First 1/4 Correlator | 0 | 0 | 0 | 0 | 0 | 0 | 28% | 0 | 0 |
| 8.8.2 | Second 1/4 Correlator | 0 | 0 | 0 | 0 | 0 | 0 | 24% | 0 | 0 |
| 8.8.3 | Third 1/4 Correlator | 0 | 0 | 0 | 0 | 0 | 0 | 24% | 0 | 0 |

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|---|---|---|---|---|---|---|---|---|---|---|
| 8.8.4 | Fourth 1/4 Correlator | 0 | 0 | 0 | 0 | 0 | 0 | 24% | 0 | 0 |
| 8.9 | Correlator test equipment | 0 | 0 | 0 | 0 | 0 | 49 | 5% | 51 | 54 |
| | | | | | | | | | | |
| 9 | Computing | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.1 | Control Software | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.1.1 | Test Interferometer Control and Analysis | 0 | 36 | 0 | 0 | 215 | 0 | 34% | 287 | 302 |
| 9.1.2 | MMA Correlator Software | 3 | 36 | 0 | 0 | 236 | 0 | 34% | 316 | 332 |
| 9.1.3 | Multi-antenna & sub-array control | 0 | 0 | 0 | 0 | 0 | 60 | 34% | 80 | 84 |
| 9.1.4 | Operators and Observers Interfaces | 0 | 18 | 0 | 0 | 107 | 0 | 34% | 144 | 151 |
| 9.1.5 | Deliver control software | 0 | 0 | 0 | 0 | 0 | 0 | 30% | 0 | 0 |
| 9.1.6 | Maintenance | 0 | 0 | 0 | 0 | 0 | 0 | 18% | 0 | 0 |
| 9.2 | Scheduling | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.2.1 | Static Scheduling System | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 9.2.2 | Dynamic scheduling simulations | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 9.2.3 | Dynamic scheduling prototype | 0 | 0 | 0 | 0 | 0 | 0 | 30% | 0 | 0 |
| 9.2.4 | Dynamic scheduling implementation | 0 | 0 | 0 | 0 | 0 | 0 | 39% | 0 | 0 |
| 9.3 | Proposal preparation software | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.3.1 | Proposal assistance prototype | 0 | 0 | 0 | 0 | 0 | 0 | 30% | 0 | 0 |
| 9.3.2 | Proposal assistance implementation | 0 | 0 | 0 | 0 | 0 | 0 | 30% | 0 | 0 |
| 9.3.3 | Observe program prototype | 0 | 0 | 0 | 0 | 0 | 0 | 26% | 0 | 0 |
| 9.3.4 | Observe program | 0 | 0 | 0 | 0 | 0 | 0 | 26% | 0 | 0 |
| 9.4 | Image pipeline | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.4.1 | Automated calibration & imaging heuristics | 0 | 0 | 0 | 0 | 0 | 0 | 39% | 0 | 0 |
| 9.4.2 | Prototype image pipeline | 0 | 0 | 0 | 0 | 0 | 0 | 30% | 0 | 0 |
| 9.4.3 | Parallelization studies and implementation | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 9.4.4 | Initial image pipeline operations | 0 | 0 | 0 | 0 | 0 | 0 | 26% | 0 | 0 |
| 9.4.5 | Production image pipeline | 0 | 0 | 0 | 0 | 0 | 0 | 30% | 0 | 0 |
| 9.5 | Archiving | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.5.1 | Prototype distributed archive | 0 | 0 | 0 | 0 | 0 | 0 | 30% | 0 | 0 |
| 9.5.2 | Evaluate storage hardware | 0 | 0 | 0 | 0 | 0 | 0 | 11% | 0 | 0 |
| 9.5.3 | Production archive | 0 | 0 | 0 | 0 | 0 | 0 | 30% | 0 | 0 |
| 9.6 | Post processing | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.6.1 | Define data formats | 0 | 0 | 0 | 0 | 0 | 0 | 18% | 0 | 0 |
| 9.6.2 | Filler and format conversions | 0 | 0 | 0 | 0 | 0 | 0 | 22% | 0 | 0 |
| 9.6.3 | ALMA specific calibrations | 0 | 0 | 0 | 0 | 0 | 0 | 39% | 0 | 0 |
| 9.6.4 | MMA Post-processing begins | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.6.5 | Maintenance | 0 | 0 | 0 | 0 | 0 | 0 | 22% | 0 | 0 |
| 9.7 | Software support | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.7.1 | Tool support | 0 | 9 | 0 | 0 | 54 | 0 | 34% | 72 | 75 |
| 9.7.2 | Quality assurance | 0 | 6 | 0 | 0 | 36 | 0 | 34% | 48 | 50 |
| 9.7.3 | Chile system administration | 0 | 0 | 0 | 0 | 0 | 0 | 22% | 0 | 0 |
| | | | | | | | | | | |
| 10 | System Integration | 0 | 0 | 0 | 0 | 0 | 0 | 10% | 0 | 0 |
| 10.4 | Test Interferometer Site Preparation | 0 | 0 | 0 | 3 | 12 | 48 | 25% | 75 | 78 |
| 10.10 | Oufitting at U.S. test site | 0 | 0 | 0 | 0 | 0 | 0 | 12% | 0 | 0 |
| 10.10.4 | Antenna #1 Outfitting | 0 | 0 | 6 | 6 | 67 | 25 | 25% | 115 | 121 |
| 10.10.7 | Antenna #2 Outfitting | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.10.10 | General Outfitting | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.11 | Single Dish Tests | 0 | 0 | 0 | 0 | 0 | 0 | 11% | 0 | 0 |
| 10.11.1 | Ant #1 holography and surface readjustment | 2 | 1 | 2 | 2 | 43 | 0 | 25% | 53 | 56 |
| 10.11.2 | Ant #1 Antenna Evaluation | 3 | 1 | 2 | 2 | 50 | 0 | 25% | 62 | 65 |
| 10.11.6 | Ant #2 holography and surface readjustment | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |

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|---|---|---|---|---|---|---|---|---|---|---|
| 10.11.7 | Ant #2 Antenna Evaluation | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.12 | Interferometric Tests | 0 | 0 | 0 | 0 | 0 | 0 | 11% | 0 | 0 |
| 10.12.1 | Phase/gain stability tests | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.12.2 | Sensitivity verification | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.12.3 | Holography with astronomical sources | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.12.4 | Modifications and Retrofits | 0 | 0 | 0 | 0 | 0 | 0 | 35% | 0 | 0 |
| 10.13 | Dissassemble test system and ship to array site | 0 | 0 | 0 | 0 | 0 | 0 | 35% | 0 | 0 |
| 10.14 | On-site System Integration | 0 | 0 | 0 | 0 | 0 | 0 | 50% | 0 | 0 |
| 10.14.1 | Set up assembly and test facilities at OSF | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.14.2 | Outfit antennas 3 through 36 | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.14.2.1 | Wiring and plumbing | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.14.2.2 | Install electronics in receiver cabin | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.14.2.3 | Check out completed antenna at OSF | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.14.2.4 | Install antenna at array site. | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.14.3 | Refurbish antennas 1 and 2 | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.14.3.1 | Re-install electronics and upgrade as needed | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.14.3.2 | Check out at OSF | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.14.3.3 | Install antenna at array site | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.14.4 | Install central building electronics | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.14.5 | Support debugging and repair | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.20 | Prototype Testing Support | 0 | 0 | 0 | 0 | 0 | 0 | 10% | 0 | 0 |
| | | | | | | | | | | |
| 11.1.1 | Completion of 183 GHz Water Vapor Radiometer | 0 | 0 | 1 | 0 | 7 | 0 | 11% | 8 | 8 |
| 11.1.2 | Demonstrate 183 GHz Water Vapor Radiometer | 0 | 0 | 0 | 11 | 43 | 20 | 12% | 70 | 74 |
| 11.1.3 | Refinement of 183 GHz Water Vapor Radiometer | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 11.1.4 | Release WVR for manufacture | 0 | 0 | 0 | 0 | 0 | 90 | 10% | 99 | 104 |
| 11.2.1.1 | Contract Phase Monitor Radiometer Subassembly | 0 | 0 | 0 | 0 | 0 | 0 | 10% | 0 | 0 |
| 11.2.1.2 | WVR Spectrometer | 0 | 0 | 0 | 1 | 4 | 7 | 10% | 12 | 13 |
| 11.2.1.3 | WVR Feed, Window, Lens, Instrumentation | 0 | 0 | 0 | 0 | 0 | 0 | 10% | 0 | 0 |
| 11.2.1.4 | Monitor and Control WVR Interface | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 11.2.3 | Deliver Production Radiometers | 0 | 0 | 0 | 0 | 0 | 0 | 9% | 0 | 0 |
| 11.2.4 | Integration of WVR into Receiver Package | 0 | 0 | 0 | 0 | 0 | 0 | 7% | 0 | 0 |
| 11.2.5 | Verification on Site of WVR | 0 | 0 | 0 | 0 | 0 | 0 | 9% | 0 | 0 |
| 11.3.1 | Dual-Load Amp. Calibration Device Design Refinement | 0 | 0 | 7 | 0 | 51 | 0 | 7% | 54 | 57 |
| 11.3.2 | Release Dual-Load Amp Cal for Mftr | 0 | 0 | 0 | 0 | 0 | 0 | 8% | 0 | 0 |
| 11.3.3 | Contract Subassembly Dual-Load Amp Cal | 0 | 0 | 0 | 0 | 0 | 0 | 7% | 0 | 0 |
| 11.3.3.1 | Dual-Load AmpCal Subassy Machining | 0 | 0 | 0 | 0 | 0 | 0 | 7% | 0 | 0 |
| 11.3.3.2 | Load Fabrication for Dual Load Amp Cal | 0 | 0 | 0 | 0 | 0 | 0 | 7% | 0 | 0 |
| 11.3.3.3 | Dual Load Amplitude Calibration Device Motors, Servo | 0 | 0 | 0 | 0 | 0 | 0 | 7% | 0 | 0 |
| 11.3.3.4 | M/C Interface for Dual Load Amp Cal Device | 0 | 0 | 0 | 0 | 0 | 0 | 7% | 0 | 0 |
| 11.3.4 | Assembly and Test of Dual Load Amplitude Calibration | 0 | 0 | 0 | 0 | 0 | 0 | 7% | 0 | 0 |
| 11.3.5 | Integration of AmpCal on Production Antennas | 0 | 0 | 0 | 0 | 0 | 0 | 7% | 0 | 0 |
| 11.4 | Imaging Studies and Project Support | 48 | 0 | 0 | 0 | 343 | 0 | 5% | 360 | 379 |
| 11.5 | Imaging Algorithm Development | 12 | 0 | 0 | 0 | 86 | 0 | 7% | 92 | 96 |
| | | | | | | | | | | |
| | Totals | 145 | 157 | 482 | 672 | 8,090 | 16,730 | | 30,540 | 32,056 |

# Millimeter Array Construction: 2002

US Reference Project

| WBS | Task Name | Scientists Work-months | Programmers Work-months | Engineers Work-months | Technicians Work-months | Personnel 1999 $K | Materials & Supplies 1999 $K | Contingency | Total Cost 1999 $K | Inflated Cost 2002 $K |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.1 | Project Management | 60 | 0 | 0 | 24 | 523 | 0 | 15% | 601 | 647 |
| 1.1.1 | Management, Planning, and Oversight | 0 | 0 | 0 | 0 | 0 | 608 | 15% | 699 | 753 |
| 1.1.2 | Business Operations | 0 | 0 | 0 | 0 | 0 | 50 | 15% | 57 | 62 |
| 1.1.3 | Chilean Operations | 0 | 0 | 0 | 0 | 0 | 15 | 15% | 17 | 19 |
| 1.1.4 | Safety and Health | 0 | 0 | 0 | 0 | 0 | 0 | 15% | 0 | 0 |
| 1.1.5 | Personnel | 0 | 0 | 0 | 0 | 0 | 0 | 15% | 0 | 0 |
| 1.1.6 | Project Science Office | 0 | 0 | 0 | 0 | 0 | 0 | 15% | 0 | 0 |
| 1.1.7 | AUI Management | 0 | 0 | 0 | 0 | 0 | 350 | 15% | 402 | 433 |
| 1.2 | Engineering | 0 | 0 | 24 | 12 | 221 | 20 | 15% | 277 | 298 |
| 1.2.1 | System Engineering--Phase II | 0 | 0 | 0 | 0 | 0 | 0 | 15% | 0 | 0 |
| 1.2.2 | Documentation System | 0 | 0 | 0 | 0 | 0 | 0 | 15% | 0 | 0 |
| 1.2.3 | Production Engineering | 0 | 0 | 0 | 0 | 0 | 0 | 15% | 0 | 0 |
| 1.3 | US Facilities | 0 | 0 | 0 | 0 | 0 | 0 | 15% | 0 | 0 |
| 1.3.1 | CDL Permanent Facilities | 0 | 0 | 0 | 0 | 0 | 600 | 0% | 600 | 600 |
| 1.3.2 | Manufacturing Facilities | 0 | 0 | 0 | 0 | 0 | 115 | 10% | 127 | 136 |
| 1.3.3 | Common Infrastructure | 0 | 0 | 0 | 0 | 0 | 200 | 15% | 230 | 248 |
| | | | | | | | | | | |
| 2 | Site Development | 0 | 0 | 12 | 0 | 87 | 50 | 5% | 144 | 155 |
| 2.2 | Maintain Mining claims | 0 | 0 | 0 | 0 | 0 | 25 | 5% | 26 | 28 |
| 2.3 | Contract A&E Studies | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 2.5.3 | Contract Array Site Civil Works | 0 | 0 | 0 | 0 | 0 | 16,223 | 20% | 19,468 | 20,964 |
| 2.6.3 | Contract OSF Civil Works | 0 | 0 | 0 | 0 | 0 | 10,607 | 20% | 12,728 | 13,707 |
| 2.7.3 | Contract Civil Works | 0 | 0 | 0 | 0 | 0 | 3,830 | 20% | 4,596 | 4,949 |
| 2.8.1 | Equip Array Site | 0 | 0 | 0 | 0 | 0 | 5,430 | 20% | 6,516 | 7,017 |
| 2.8.2 | Equip Operations Support Facility | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| | | | | | | | | | | |
| 3.1 | Antenna Engineering Support | 0 | 0 | 48 | 0 | 348 | 0 | 14% | 397 | 428 |
| 3.8.10 | Sign Transporter Contract | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 3.8.30 | Accept Transporter #2 at OSF | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 3.8.35 | Contract for Transporter #1 Move to site | 0 | 0 | 0 | 0 | 0 | 0 | 12% | 0 | 0 |
| 3.15 | Procurement of Antenna 2 | 0 | 0 | 0 | 0 | 0 | 0 | 27% | 0 | 0 |
| 3.20 | Sign Contract for Production Antennas | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 3.21 | Antenna Contract Supervision | 0 | 0 | 0 | 0 | 0 | 0 | 12% | 0 | 0 |
| 3.23 | Accept Antenna #3 at OSF | 0 | 0 | 0 | 0 | 0 | 0 | 27% | 0 | 0 |
| 3.25, 3.27, 3.2 | Accept Antennas #4 through #36 | 0 | 0 | 0 | 0 | 0 | 0 | 27% | 0 | 0 |
| | | | | | | | | | | |
| 4.1.1.2 | Fabricate PPRC | 0 | 0 | 0 | 0 | 0 | 0 | 28% | 0 | 0 |
| 4.1.1.3 | Test PPRC | 0 | 0 | 0 | 0 | 0 | 0 | 5% | 0 | 0 |
| 4.1.2.1 | PPR Dewar Design | 0 | 0 | 0 | 0 | 0 | 0 | 17% | 0 | 0 |
| 4.1.2.2 | PPR Dewar Fabrication and Vacuum Testing | 0 | 0 | 0 | 0 | 0 | 0 | 40% | 0 | 0 |
| 4.1.2.3 | PPR Vacuum Windows and IR Filters | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 4.1.2.4 | PPR Cryogenics/Dewar Assembly and Testing | 0 | 0 | 0 | 0 | 0 | 0 | 13% | 0 | 0 |
| 4.1.3.1 | PPR Control-Monitoring and Bias Electronics Design | 0 | 0 | 0 | 0 | 0 | 0 | 21% | 0 | 0 |
| 4.1.3.2 | PPR Control-Monitor and Bias Electronics Construction | 0 | 0 | 0 | 0 | 0 | 0 | 44% | 0 | 0 |
| 4.1.4.1 | Insert Mechanical-Thermal Design, Bands <275 GHz (Waveguide | 0 | 0 | 0 | 0 | 0 | 0 | 48% | 0 | 0 |
| 4.1.4.2 | Insert Component Fabrication for Bands <275 GHz | 0 | 0 | 0 | 0 | 0 | 0 | 56% | 0 | 0 |
| 4.1.4.3 | Insert Mechanical-Thermal Design for Bands >275 GHz (Quasi o | 0 | 0 | 0 | 0 | 0 | 0 | 48% | 0 | 0 |
| 4.1.4.4 | Insert Component Fabrication for Bands >275 Ghz | 0 | 0 | 0 | 0 | 0 | 0 | 56% | 0 | 0 |
| 4.1.4.8 | PPR Insert Assembly (3 Bands) | 0 | 0 | 0 | 0 | 0 | 0 | 44% | 0 | 0 |
| 4.1.4.9 | PPR Insert Testing (3 Bands) | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.1.5.1 | PPR Vacuum System Assembly | 0 | 0 | 0 | 0 | 0 | 0 | 8% | 0 | 0 |
| 4.1.7.1 | PPR Post IF System Design | 0 | 0 | 0 | 0 | 0 | 0 | 22% | 0 | 0 |

# Millimeter Array Construction: 2002

US Reference Project

| WBS | Task Name | Scientists Work-months | Programmers Work-months | Engineers Work-months | Technicians Work-months | Personnel 1999 $K | Materials & Supplies 1999 $K | Contingency | Total Cost 1999 $K | Inflated Cost 2002 $K |
|---|---|---|---|---|---|---|---|---|---|---|
| 4.1.7.2 | PPR Post IF System Construction and Testing | 0 | 0 | 0 | 0 | 0 | 0 | 24% | 0 | 0 |
| 4.1.8.1 | PPR Frame Design | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.1.8.2 | PPR Frame Fabrication | 0 | 0 | 0 | 0 | 0 | 0 | 30% | 0 | 0 |
| 4.1.9.1 | Prototype Production Receiver Integration | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.1.9.2 | PPR Testing and Evaluation | 0 | 1 | 3 | 4 | 43 | 37 | 36% | 109 | 118 |
| 4.1.10.1 | Design and build Prototype and Production Receiver Test Set | 0 | 0 | 0 | 0 | 0 | 0 | 36% | 0 | 0 |
| 4.1.10.2 | Design and Fabricate Receiver Insert Test Set | 0 | 0 | 0 | 0 | 0 | 0 | 11% | 0 | 0 |
| 4.1.10.3 | General Test Equipment | 0 | 0 | 0 | 0 | 0 | 0 | 13% | 0 | 0 |
| 4.2.1 | MMA Receiver (MMA Rx) Design Refinement | 0 | 0 | 6 | 2 | 51 | 0 | 28% | 66 | 71 |
| 4.2.2 | MMA Receiver (MMA Rx) Documentation | 0 | 0 | 2 | 4 | 30 | 5 | 18% | 41 | 45 |
| 4.2.4.1 | MMA Rx Dewar Fabrication | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.2.4.2 | MMA Rx Cryogenics Fabrication | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 4.2.4.3 | Vacuum Windows and IR Filters Fabrication | 0 | 0 | 2 | 11 | 57 | 55 | 16% | 130 | 140 |
| 4.2.4.4 | Receiver Insert Fabrication | 0 | 0 | 0 | 0 | 0 | 0 | 22% | 0 | 0 |
| 4.2.4.5 | MMA Receiver Frame Fabrication and assembly | 0 | 0 | 1 | 0 | 7 | 0 | 16% | 8 | 9 |
| 4.2.4.6 | Vacuum System Fabrication and testing. | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.2.4.7 | Bias and Control-Monitoring Electronics Construction | 0 | 0 | 1 | 2 | 15 | 0 | 16% | 17 | 19 |
| 4.2.4.9 | Assemble Receiver Inserts and Test | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 4.2.4.10 | Assemble MMA Rx IF System | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.2.6.1 | Integrate Test & Commission MMA Receivers | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.5.1 | Construct and test Cryo system for 2nd Evaluation Receiver | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.5.2 | Fabrication and assembly of 2nd Evaluation Receiver. | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.5.3 | Test and Commission 2nd Evaluation Receiver | 0 | 0 | 0 | 0 | 0 | 0 | 5% | 0 | 0 |
| 4.3.1.1 | Design, Fab, and Test 211-275 GHz Mixer Design | 0 | 0 | 0 | 0 | 0 | 0 | 52% | 0 | 0 |
| 4.3.1.3 | Fabricate 211-275 GHz mixer blocks | 0 | 0 | 0 | 5 | 20 | 3 | 16% | 26 | 27 |
| 4.3.1.4 | Fabricate & test 211-275 GHz SIS Mixer Detector Modules | 0 | 0 | 9 | 22 | 151 | 265 | 52% | 633 | 682 |
| 4.3.2.1 | Design, Fab, and Test 602-720 GHz Mixer Design | 0 | 0 | 0 | 0 | 0 | 0 | 52% | 0 | 0 |
| 4.3.2.3 | Fabricate 602-720 GHz mixer blocks | 0 | 0 | 0 | 7 | 27 | 3 | 16% | 35 | 38 |
| 4.3.2.4 | Fabricate & test 602-720 GHz SIS Mixer Detector Modules | 0 | 0 | 9 | 22 | 151 | 289 | 78% | 784 | 844 |
| 4.3.3.1 | Design, Fab, and Test 275-370 GHz Mixer Design | 0 | 0 | 24 | 29 | 287 | 327 | 52% | 934 | 1,006 |
| 4.3.3.3 | Fabricate 275-370 GHz mixer blocks | 0 | 0 | 0 | 5 | 20 | 5 | 16% | 28 | 30 |
| 4.3.3.4 | Fabricate & test 275-370 GHz SIS Mixer Detector Modules | 0 | 0 | 12 | 30 | 204 | 384 | 52% | 894 | 963 |
| 4.3.4.1 | Design, Fab, and Test 89-116 GHz Mixer Design | 0 | 0 | 32 | 39 | 384 | 367 | 52% | 1,142 | 1,230 |
| 4.3.4.3 | Fabricate 89-116 GHz mixer blocks | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.3.4.4 | Fabricate 89-116 GHz SIS Mixer Detector Modules | 0 | 0 | 0 | 0 | 0 | 0 | 52% | 0 | 0 |
| 4.3.5.1 | Design, Fab, and Test 163-211 GHz Mixer Design | 0 | 0 | 0 | 0 | 0 | 0 | 52% | 0 | 0 |
| 4.3.5.3 | Fabricate 163-211 GHz Mixer Blocks | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.3.5.4 | Fabricate & test 163-211 GHz SIS Mixer Detector Modules | 0 | 0 | 0 | 0 | 0 | 0 | 52% | 0 | 0 |
| 4.3.6.1 | Design, Fab, and Test 385-500 GHz Mixer Design | 0 | 0 | 0 | 0 | 0 | 0 | 52% | 0 | 0 |
| 4.3.6.3 | Fabricate 385-500 GHz mixer blocks | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.3.6.4 | Fabricate & Test 385-500 GHz SIS Mixer Detector Modules | 0 | 0 | 0 | 0 | 0 | 0 | 52% | 0 | 0 |
| 4.3.7.1 | Design, Fab, and Test 125-163 GHz Mixer Design | 0 | 0 | 0 | 0 | 0 | 0 | 52% | 0 | 0 |
| 4.3.7.3 | Fabricate 125-163 GHz mixer blocks | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.3.7.4 | Fabricate & Test 125-163 GHz SIS Mixer Detector Modules | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 4.3.8.1 | Build SIS Fabrication Equipment | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.3.8.2 | Build SIS Test Dewar & Rack #1 | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.3.8.3 | Build SIS Test Dewar & Rack #2 | 0 | 0 | 2 | 10 | 54 | 0 | 14% | 61 | 66 |
| 4.3.8.4 | Build SIS Test Dewar & Rack #3 | 0 | 0 | 4 | 14 | 84 | 0 | 14% | 95 | 103 |
| 4.3.8.5 | Build SIS Test Dewar & Rack #4 | 0 | 0 | 4 | 20 | 107 | 0 | 14% | 122 | 131 |
| 4.3.8.6 | Build Wafer Evaluation Test Sets | 0 | 0 | 0 | 0 | 0 | 0 | 18% | 0 | 0 |
| 4.3.8.7.1 | General SIS Test Equipment | 0 | 0 | 0 | 0 | 0 | 63 | 5% | 66 | 71 |
| 4.3.8.7.2 | Equip Network Analyzer to 330 GHz | 0 | 0 | 1 | 0 | 7 | 104 | 15% | 128 | 138 |

# Millimeter Array Construction: 2002

US Reference Project

| WBS | Task Name | Scientists Work-months | Programmers Work-months | Engineers Work-months | Technicians Work-months | Personnel 1999 $K | Materials & Supplies 1999 $K | Contingency | Total Cost 1999 $K | Inflated Cost 2002 $K |
|---|---|---|---|---|---|---|---|---|---|---|
| 4.3.8.7.3 | Near-Field Antenna Test Equipment | 0 | 0 | 12 | 12 | 134 | 30 | 15% | 188 | 202 |
| 4.3.8.8 | Build 211-275 GHz Test Plates | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.3.8.9 | Build 602-720 GHz Test Plates | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.3.8.10 | Build 275-370 GHz Test Plates | 0 | 0 | 6 | 6 | 67 | 240 | 14% | 350 | 377 |
| 4.3.8.11 | Build 89-116 GHz Test Plates | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.3.8.12 | Build 163-211 GHz Test Plates | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.3.8.13 | Build 385-500 GHz Test Plates | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.3.8.14 | Build 125-163 GHz Test Plates | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.3.9.1 | Obtain and evaluate InP IF amplifier wafers | 0 | 0 | 0 | 0 | 0 | 0 | 10% | 0 | 0 |
| 4.3.9.2 | Build IF amplifiers | 0 | 0 | 6 | 32 | 168 | 104 | 10% | 300 | 323 |
| 4.4.1 | Contract for HFET wafer | 0 | 0 | 0 | 0 | 0 | 0 | 24% | 0 | 0 |
| 4.4.2 | Receive and evaluate InP LNA wafer | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.4.3.1 | Build 31-45 GHz HFET Detector Modules | 0 | 0 | 9 | 23 | 155 | 74 | 10% | 252 | 271 |
| 4.4.4.1 | Design 67-90 GHz amplifier | 0 | 0 | 4 | 4 | 45 | 2 | 26% | 59 | 63 |
| 4.4.4.2 | Build 67-90 GHz HFET Detector Modules | 0 | 0 | 6 | 18 | 114 | 74 | 14% | 214 | 230 |
| | | | | | | | | | | |
| 5.1 | LO Reference: Prototype Systems | 0 | 0 | 12 | 24 | 181 | 0 | 20% | 217 | 234 |
| 5.2.1 | Production test and lab equipment | 0 | 0 | 0 | 0 | 0 | 282 | 10% | 310 | 334 |
| 5.2.2 | H-maser Frequency Standard (& Rb) | 0 | 0 | 1 | 1 | 11 | 300 | 8% | 336 | 362 |
| 5.2.3 | 8 GHz PL Oscillator & Distributor | 0 | 0 | 1 | 2 | 15 | 41 | 12% | 63 | 67 |
| 5.2.4 | 10 GHz PL Oscillator & Distributor | 0 | 0 | 1 | 2 | 15 | 41 | 12% | 63 | 67 |
| 5.2.5 | 12 GHz PL Oscillator & Distributor | 0 | 0 | 1 | 2 | 15 | 41 | 12% | 63 | 67 |
| 5.2.6 | 14 GHz PL Oscillator & Distributor | 0 | 0 | 1 | 2 | 15 | 41 | 12% | 63 | 67 |
| 5.2.7 | 3.2-5.2 GHz Synthesizer | 0 | 0 | 2 | 12 | 61 | 384 | 16% | 517 | 556 |
| 5.2.8 | 3.2 -5.2 GHz PLO and Fringe Generator | 0 | 0 | 3 | 6 | 45 | 134 | 14% | 205 | 220 |
| 5.2.9 | Sampler Clock 4 GHz PL Osc & Distributor | 0 | 0 | 1 | 3 | 19 | 41 | 12% | 67 | 72 |
| 5.2.10 | LO Ref Generator | 0 | 0 | 1 | 1 | 11 | 15 | 12% | 30 | 32 |
| 5.2.11 | LO Ref Distributor - Control Bldg | 0 | 0 | 1 | 1 | 11 | 22 | 14% | 37 | 40 |
| 5.2.12 | Microwave Round-trip Phase Measurement | 0 | 0 | 2 | 3 | 26 | 120 | 49% | 217 | 234 |
| 5.2.13 | 10-15 GHz Frequency Synthesizer | 0 | 0 | 2 | 7 | 42 | 81 | 49% | 183 | 197 |
| 5.2.14 | First LO Fringe Generator | 0 | 0 | 3 | 6 | 45 | 134 | 16% | 208 | 224 |
| 5.2.15 | 16 GHz PL Oscillator & Distributor | 0 | 0 | 1 | 2 | 15 | 41 | 12% | 63 | 67 |
| 5.2.16 | 26 GHz PL Oscillator & Distributor | 0 | 0 | 1 | 2 | 15 | 41 | 12% | 63 | 67 |
| 5.2.17 | LO Ref Distributor - Antenna | 0 | 0 | 1 | 2 | 15 | 54 | 18% | 82 | 88 |
| 5.2.18 | VXCO Clean-up Loop | 0 | 0 | 1 | 2 | 15 | 122 | 100% | 273 | 294 |
| 5.2.19 | Power supply module | 0 | 0 | 2 | 2 | 22 | 22 | 5% | 46 | 50 |
| 5.2.20 | Bins / Racks (assemble and test) | 0 | 0 | 0 | 0 | 0 | 13 | 14% | 15 | 16 |
| 5.3.1 | LO Source Design and System Integration | 0 | 0 | 12 | 18 | 157 | 20 | 36% | 241 | 260 |
| 5.3.2.1 | 72-95 GHz LO Source Procurement & Fabrication | 0 | 0 | 2 | 12 | 61 | 229 | 24% | 360 | 388 |
| 5.3.2.2 | 72-95 GHz LO Source Assembly & Test | 0 | 0 | 2 | 2 | 22 | 5 | 24% | 34 | 36 |
| 5.3.3.1 | 102-120 GHz LO Source Procurement & Fabrication | 0 | 0 | 2 | 12 | 61 | 229 | 24% | 360 | 388 |
| 5.3.3.2 | 102-120 GHz LO Source Assembly & Test | 0 | 0 | 2 | 2 | 22 | 5 | 24% | 34 | 36 |
| 5.3.4.1 | 87-108 GHz LO Source Procurement & Fabrication | 0 | 0 | 0 | 0 | 0 | 0 | 24% | 0 | 0 |
| 5.3.4.2 | 87-108 GHz LO Source Assembly & Test | 0 | 0 | 0 | 0 | 0 | 0 | 24% | 0 | 0 |
| 5.3.5.1 | 65-86 GHz LO Source Procurement & Fabrication | 0 | 0 | 0 | 0 | 0 | 0 | 24% | 0 | 0 |
| 5.3.5.2 | 65-86 GHz LO Source Assembly & Test | 0 | 0 | 0 | 0 | 0 | 0 | 24% | 0 | 0 |
| 5.4.1 | LO Multiplier Chain Design & System Integration | 0 | 0 | 18 | 18 | 201 | 335 | 36% | 729 | 785 |
| 5.4.2.1 | 211-275 GHz Receiver LO multiplier Parts | 0 | 0 | 1 | 5 | 27 | 30 | 34% | 77 | 82 |
| 5.4.2.2 | 211-275 GHz Receiver LO Multiplier Assembly & Test | 0 | 0 | 1 | 2 | 11 | 0 | 34% | 15 | 16 |
| 5.4.2.3 | 275-370 GHz LO integrate source & multiplier | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.3.1 | 602-720 GHz Receiver LO multiplier Parts | 0 | 0 | 2 | 8 | 46 | 61 | 34% | 143 | 154 |
| 5.4.3.2 | 602-720 GHz Receiver LO multiplier Assembly & Test | 0 | 0 | 1 | 2 | 15 | 0 | 34% | 20 | 22 |

# Millimeter Array Construction: 2002

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| WBS | Task Name | Scientists Work-months | Programmers Work-months | Engineers Work-months | Technicians Work-months | Personnel 1999 $K | Materials & Supplies 1999 $K | Contingency | Total Cost 1999 $K | Inflated Cost 2002 $K |
|---|---|---|---|---|---|---|---|---|---|---|
| 5.4.3.3 | 602-720 GHz LO integrate source & multiplier | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.4.1 | 275-370 GHz Receiver LO multiplier Parts | 0 | 0 | 2 | 8 | 46 | 61 | 34% | 143 | 154 |
| 5.4.4.2 | 275-370 GHz Receiver LO multiplier Assembly & Test | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.4.3 | 275-370 GHz LO integrate source & multiplier | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.5.1 | 163-211 GHz Receiver LO multiplier Parts | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.5.2 | 163-211 GHz Receiver LO multiplier Assembly & Test | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.5.3 | 163-211 GHz LO integrate source & multiplier | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.6.1 | 385-500 GHz Receiver LO multiplier Parts | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.6.2 | 385-500 GHz Receiver LO multiplier Assembly & Test | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.6.3 | 385-500 GHz LO integrate source & multiplier | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.7.1 | 125-163 GHz Receiver LO multiplier Parts | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.7.2 | 125-163 GHz Receiver LO multiplier Assembly & Test | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.7.3 | 125-163 GHz LO integrate source & multiplier | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.8.1 | Design & fab 31-45 GHz receiver LO coupling | 0 | 0 | 4 | 6 | 52 | 9 | 12% | 69 | 74 |
| 5.4.9 | LO Multiplier Fabrication Equipment | 0 | 0 | 0 | 0 | 0 | 24 | 11% | 26 | 28 |
| 5.4.10 | LO Multiplier Test Equipment | 0 | 0 | 1 | 0 | 7 | 163 | 11% | 189 | 204 |
| | | | | | | | | | | |
| 6.1 | IF Field Prototype for Test Interferometer of 2 antennas. | 0 | 0 | 6 | 9 | 79 | 0 | 10% | 87 | 93 |
| 6.2 | IF Construction test & lab equipment | 0 | 0 | 3 | 3 | 33 | 0 | 5% | 35 | 38 |
| 6.3 | IF Multiplexer (2/antenna) | 0 | 0 | 3 | 6 | 45 | 578 | 20% | 748 | 805 |
| 6.4 | IF Demultiplexer (2/antenna) | 0 | 0 | 3 | 4 | 37 | 204 | 10% | 266 | 286 |
| 6.5 | IF Matrix Switch (2/antenna) | 0 | 0 | 3 | 4 | 37 | 127 | 6% | 174 | 187 |
| 6.6 | IF Baseband Converter (8/antenna) | 0 | 0 | 3 | 4 | 37 | 492 | 20% | 635 | 683 |
| 6.7 | IF Power Supply module | 0 | 0 | 1 | 2 | 15 | 16 | 5% | 33 | 35 |
| 6.8 | Bins / Racks (assemble and test) | 0 | 0 | 2 | 4 | 30 | 38 | 5% | 71 | 77 |
| | | | | | | | | | | |
| 7.1 | Prototype Optical Fiber Systems | 0 | 0 | 18 | 24 | 224 | 0 | 32% | 296 | 319 |
| 7.2 | Digital IF Transmitters and Receivers | 0 | 0 | 15 | 0 | 109 | 935 | 40% | 1,461 | 1,573 |
| 7.3.1 | 16 GHZ FO LO Ref Dist Prototype | 0 | 0 | 18 | 36 | 271 | 0 | 40% | 379 | 409 |
| 7.3.2 | 16 GHz FO LO Ref Dist with Integrated R/T Phase Meas. | 0 | 0 | 12 | 12 | 134 | 268 | 28% | 514 | 554 |
| 7.4 | Production Test Equipment | 0 | 0 | 0 | 0 | 0 | 0 | 5% | 0 | 0 |
| 7.5 | Monitor and Control Transmitters and Receivers | 0 | 0 | 4 | 10 | 68 | 52 | 14% | 137 | 148 |
| 7.6 | Fiber Optics Power Supply Modules | 0 | 0 | 4 | 4 | 45 | 18 | 14% | 72 | 77 |
| 7.7 | Bins / Racks (assemble and test) | 0 | 0 | 4 | 6 | 52 | 22 | 14% | 85 | 92 |
| | | | | | | | | | | |
| 8.1.1 | Refine digitizer design | 0 | 0 | 0 | 0 | 0 | 0 | 30% | 0 | 0 |
| 8.1.3 | Digitizer contract materials | 0 | 0 | 3 | 3 | 33 | 928 | 30% | 1,250 | 1,346 |
| 8.1.4 | Assembly of digitizers | 0 | 0 | 1 | 23 | 97 | 0 | 26% | 122 | 132 |
| 8.1.5 | Digitizer validation and delivery | 0 | 0 | 1 | 1 | 11 | 5 | 26% | 20 | 22 |
| 8.2.1 | Prototype FIR filter testing on interferometer | 0 | 0 | 0 | 0 | 0 | 0 | 38% | 0 | 0 |
| 8.2.2 | Design & test FIR filter refinement | 0 | 0 | 0 | 0 | 0 | 0 | 32% | 0 | 0 |
| 8.2.4 | FIR filter chip & board fabrication | 0 | 0 | 0 | 0 | 0 | 650 | 32% | 858 | 924 |
| 8.2.5 | FIR filter board assembly | 0 | 0 | 1 | 6 | 31 | 5 | 26% | 45 | 48 |
| 8.2.6 | FIR filter board validation and delivery | 0 | 0 | 2 | 2 | 22 | 0 | 32% | 29 | 32 |
| 8.3.1 | Correlator boards | 0 | 0 | 0 | 0 | 0 | 0 | 26% | 0 | 0 |
| 8.4 | Correlator Chip | 0 | 0 | 12 | 4 | 103 | 2,225 | 30% | 3,026 | 3,259 |
| 8.6 | Correlator software | 0 | 12 | 0 | 0 | 72 | 5 | 20% | 92 | 99 |
| 8.5 | Correlator Racks | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 8.7 | Prototype Correlator Production | 0 | 0 | 24 | 32 | 299 | 104 | 28% | 516 | 556 |
| 8.8.1 | First 1/4 Correlator | 0 | 0 | 0 | 0 | 0 | 0 | 28% | 0 | 0 |
| 8.8.2 | Second 1/4 Correlator | 0 | 0 | 0 | 0 | 0 | 0 | 24% | 0 | 0 |
| 8.8.3 | Third 1/4 Correlator | 0 | 0 | 0 | 0 | 0 | 0 | 24% | 0 | 0 |

# Millimeter Array Construction: 2002

US Reference Project

| WBS | Task Name | Scientists Work-months | Programmers Work-months | Engineers Work-months | Technicians Work-months | Personnel 1999 $K | Materials & Supplies 1999 $K | Contingency | Total Cost 1999 $K | Inflated Cost 2002 $K |
|---|---|---|---|---|---|---|---|---|---|---|
| 8.8.4 | Fourth 1/4 Correlator | 0 | 0 | 0 | 0 | 0 | 0 | 24% | 0 | 0 |
| 8.9 | Correlator test equipment | 0 | 0 | 0 | 0 | 0 | 0 | 5% | 0 | 0 |
| | | | | | | | | | | |
| 9 | Computing | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.1 | Control Software | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.1.1 | Test Interferometer Control and Analysis | 0 | 12 | 0 | 0 | 72 | 0 | 34% | 96 | 103 |
| 9.1.2 | MMA Correlator Software | 3 | 36 | 0 | 0 | 236 | 0 | 34% | 316 | 340 |
| 9.1.3 | Multi-antenna & sub-array control | 0 | 12 | 0 | 0 | 72 | 0 | 34% | 96 | 103 |
| 9.1.4 | Operators and Observers Interfaces | 0 | 18 | 0 | 0 | 107 | 0 | 34% | 144 | 155 |
| 9.1.5 | Deliver control software | 0 | 0 | 0 | 0 | 0 | 0 | 30% | 0 | 0 |
| 9.1.6 | Maintenance | 0 | 0 | 0 | 0 | 0 | 0 | 18% | 0 | 0 |
| 9.2 | Scheduling | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.2.1 | Static Scheduling System | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 9.2.2 | Dynamic scheduling simulations | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 9.2.3 | Dynamic scheduling prototype | 0 | 0 | 0 | 0 | 0 | 0 | 30% | 0 | 0 |
| 9.2.4 | Dynamic scheduling implementation | 0 | 0 | 0 | 0 | 0 | 0 | 39% | 0 | 0 |
| 9.3 | Proposal preparation software | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.3.1 | Proposal assistance prototype | 0 | 0 | 0 | 0 | 0 | 0 | 30% | 0 | 0 |
| 9.3.2 | Proposal assistance implementation | 0 | 0 | 0 | 0 | 0 | 0 | 30% | 0 | 0 |
| 9.3.3 | Observe program prototype | 0 | 0 | 0 | 0 | 0 | 0 | 26% | 0 | 0 |
| 9.3.4 | Observe program | 0 | 0 | 0 | 0 | 0 | 0 | 26% | 0 | 0 |
| 9.4 | Image pipeline | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.4.1 | Automated calibration & imaging heuristics | 0 | 0 | 0 | 0 | 0 | 0 | 39% | 0 | 0 |
| 9.4.2 | Prototype image pipeline | 0 | 0 | 0 | 0 | 0 | 0 | 30% | 0 | 0 |
| 9.4.3 | Parallelization studies and implementation | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 9.4.4 | Initial image pipeline operations | 0 | 0 | 0 | 0 | 0 | 0 | 26% | 0 | 0 |
| 9.4.5 | Production image pipeline | 0 | 0 | 0 | 0 | 0 | 0 | 30% | 0 | 0 |
| 9.5 | Archiving | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.5.1 | Prototype distributed archive | 0 | 0 | 0 | 0 | 0 | 0 | 30% | 0 | 0 |
| 9.5.2 | Evaluate storage hardware | 0 | 0 | 0 | 0 | 0 | 0 | 11% | 0 | 0 |
| 9.5.3 | Production archive | 0 | 0 | 0 | 0 | 0 | 0 | 30% | 0 | 0 |
| 9.6 | Post processing | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.6.1 | Define data formats | 6 | 0 | 0 | 0 | 43 | 0 | 18% | 51 | 55 |
| 9.6.2 | Filler and format conversions | 0 | 0 | 0 | 0 | 0 | 0 | 22% | 0 | 0 |
| 9.6.3 | ALMA specific calibrations | 0 | 0 | 0 | 0 | 0 | 0 | 39% | 0 | 0 |
| 9.6.4 | MMA Post-processing begins | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.6.5 | Maintenance | 0 | 0 | 0 | 0 | 0 | 0 | 22% | 0 | 0 |
| 9.7 | Software support | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.7.1 | Tool support | 0 | 9 | 0 | 0 | 54 | 0 | 34% | 72 | 77 |
| 9.7.2 | Quality assurance | 0 | 6 | 0 | 0 | 36 | 0 | 34% | 48 | 52 |
| 9.7.3 | Chile system administration | 0 | 0 | 0 | 0 | 0 | 0 | 22% | 0 | 0 |
| | | | | | | | | | | |
| 10 | System Integration | 0 | 0 | 0 | 0 | 0 | 125 | 10% | 138 | 148 |
| 10.4 | Test Interferometer Site Preparation | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.10 | Oufitting at U.S. test site | 0 | 0 | 0 | 0 | 0 | 0 | 12% | 0 | 0 |
| 10.10.4 | Antenna #1 Outfitting | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.10.7 | Antenna #2 Outfitting | 0 | 0 | 6 | 6 | 67 | 25 | 25% | 115 | 124 |
| 10.10.10 | General Outfitting | 0 | 0 | 12 | 12 | 134 | 55 | 25% | 236 | 254 |
| 10.11 | Single Dish Tests | 0 | 0 | 0 | 0 | 0 | 0 | 11% | 0 | 0 |
| 10.11.1 | Ant #1 holography and surface readjustment | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.11.2 | Ant #1 Antenna Evaluation | 3 | 1 | 2 | 2 | 50 | 0 | 25% | 62 | 67 |
| 10.11.6 | Ant #2 holography and surface readjustment | 2 | 1 | 2 | 2 | 43 | 0 | 25% | 53 | 57 |

# Millimeter Array Construction: 2002

US Reference Project

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|---|---|---|---|---|---|---|---|---|---|---|
| 10.11.7 | Ant #2 Antenna Evaluation | 6 | 2 | 4 | 4 | 99 | 0 | 25% | 124 | 134 |
| 10.12 | Interferometric Tests | 0 | 0 | 0 | 0 | 0 | 0 | 11% | 0 | 0 |
| 10.12.1 | Phase/gain stability tests | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.12.2 | Sensitivity verification | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.12.3 | Holography with astronomical sources | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.12.4 | Modifications and Retrofits | 0 | 0 | 0 | 0 | 0 | 0 | 35% | 0 | 0 |
| 10.13 | Dissassemble test system and ship to array site | 0 | 0 | 0 | 0 | 0 | 0 | 35% | 0 | 0 |
| 10.14 | On-site System Integration | 0 | 0 | 0 | 0 | 0 | 0 | 50% | 0 | 0 |
| 10.14.1 | Set up assembly and test facilities at OSF | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.14.2 | Outfit antennas 3 through 36 | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.14.2.1 | Wiring and plumbing | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.14.2.2 | Install electronics in receiver cabin | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.14.2.3 | Check out completed antenna at OSF | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.14.2.4 | Install antenna at array site. | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.14.3 | Refurbish antennas 1 and 2 | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.14.3.1 | Re-install electronics and upgrade as needed | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.14.3.2 | Check out at OSF | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.14.3.3 | Install antenna at array site | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.14.4 | Install central building electronics | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.14.5 | Support debugging and repair | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.20 | Prototype Testing Support | 0 | 0 | 1 | 1 | 11 | 10 | 10% | 23 | 25 |
| | | | | | | | | | | |
| 11.1.1 | Completion of 183 GHz Water Vapor Radiometer | 0 | 0 | 0 | 0 | 0 | 0 | 11% | 0 | 0 |
| 11.1.2 | Demonstrate 183 GHz Water Vapor Radiometer | 0 | 0 | 0 | 1 | 4 | 0 | 12% | 4 | 5 |
| 11.1.3 | Refinement of 183 GHz Water Vapor Radiometer | 0 | 0 | 3 | 3 | 33 | 0 | 16% | 39 | 42 |
| 11.1.4 | Release WVR for manufacture | 0 | 0 | 0 | 0 | 0 | 210 | 10% | 231 | 249 |
| 11.2.1.1 | Contract Phase Monitor Radiometer Subassembly | 0 | 0 | 0 | 0 | 0 | 210 | 10% | 231 | 249 |
| 11.2.1.2 | WVR Spectrometer | 0 | 0 | 0 | 0 | 0 | 60 | 10% | 66 | 71 |
| 11.2.1.3 | WVR Feed, Window, Lens, Instrumentation | 0 | 0 | 0 | 0 | 0 | 140 | 10% | 154 | 166 |
| 11.2.1.4 | Monitor and Control WVR Interface | 0 | 0 | 0 | 0 | 0 | 15 | 14% | 17 | 18 |
| 11.2.3 | Deliver Production Radiometers | 0 | 0 | 0 | 0 | 0 | 11 | 9% | 11 | 12 |
| 11.2.4 | Integration of WVR into Receiver Package | 0 | 0 | 0 | 0 | 0 | 0 | 7% | 0 | 0 |
| 11.2.5 | Verification on Site of WVR | 0 | 0 | 0 | 0 | 0 | 0 | 9% | 0 | 0 |
| 11.3.1 | Dual-Load Amp. Calibration Device Design Refinement | 0 | 0 | 2 | 0 | 15 | 0 | 7% | 16 | 17 |
| 11.3.2 | Release Dual-Load Amp Cal for Mftr | 0 | 0 | 0 | 0 | 0 | 0 | 8% | 0 | 0 |
| 11.3.3 | Contract Subassembly Dual-Load Amp Cal | 0 | 0 | 0 | 0 | 0 | 0 | 7% | 0 | 0 |
| 11.3.3.1 | Dual-Load AmpCal Subassy Machining | 0 | 0 | 0 | 1 | 4 | 32 | 7% | 38 | 41 |
| 11.3.3.2 | Load Fabrication for Dual Load Amp Cal | 0 | 0 | 0 | 4 | 16 | 27 | 7% | 45 | 49 |
| 11.3.3.3 | Dual Load Amplitude Calibration Device Motors, Servo | 0 | 0 | 0 | 4 | 16 | 27 | 7% | 45 | 49 |
| 11.3.3.4 | M/C Interface for Dual Load Amp Cal Device | 0 | 0 | 0 | 7 | 27 | 48 | 7% | 81 | 87 |
| 11.3.4 | Assembly and Test of Dual Load Amplitude Calibration | 0 | 0 | 0 | 0 | 0 | 0 | 7% | 0 | 0 |
| 11.3.5 | Integration of AmpCal on Production Antennas | 0 | 0 | 0 | 0 | 0 | 0 | 7% | 0 | 0 |
| 11.4 | Imaging Studies and Project Support | 0 | 0 | 0 | 0 | 0 | 0 | 5% | 0 | 0 |
| 11.5 | Imaging Algorithm Development | 12 | 0 | 0 | 0 | 86 | 0 | 7% | 92 | 99 |
| | | | | | | | | | | |
| | Totals | 92 | 110 | 502 | 780 | 7,995 | 51,358 | | 72,722 | 78,267 |

# Millimeter Array Construction: 2003

US Reference Project

| WBS | Task Name | Scientists Work-months | Programmers Work-months | Engineers Work-months | Technicians Work-months | Personnel 1999 $K | Materials & Supplies 1999 $K | Contingency | Total Cost 1999 $K | Inflated Cost 2003 $K |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.1 | Project Management | 60 | 0 | 0 | 24 | 523 | 0 | 15% | 601 | 663 |
| 1.1.1 | Management, Planning, and Oversight | 0 | 0 | 0 | 0 | 0 | 609 | 15% | 700 | 773 |
| 1.1.2 | Business Operations | 0 | 0 | 0 | 0 | 0 | 90 | 15% | 103 | 114 |
| 1.1.3 | Chilean Operations | 0 | 0 | 0 | 0 | 0 | 15 | 15% | 17 | 19 |
| 1.1.4 | Safety and Health | 0 | 0 | 0 | 0 | 0 | 0 | 15% | 0 | 0 |
| 1.1.5 | Personnel | 0 | 0 | 0 | 0 | 0 | 0 | 15% | 0 | 0 |
| 1.1.6 | Project Science Office | 0 | 0 | 0 | 0 | 0 | 0 | 15% | 0 | 0 |
| 1.1.7 | AUI Management | 0 | 0 | 0 | 0 | 0 | 350 | 15% | 402 | 444 |
| 1.2 | Engineering | 0 | 0 | 24 | 12 | 221 | 20 | 15% | 277 | 306 |
| 1.2.1 | System Engineering--Phase II | 0 | 0 | 0 | 0 | 0 | 0 | 15% | 0 | 0 |
| 1.2.2 | Documentation System | 0 | 0 | 0 | 0 | 0 | 0 | 15% | 0 | 0 |
| 1.2.3 | Production Engineering | 0 | 0 | 0 | 0 | 0 | 0 | 15% | 0 | 0 |
| 1.3 | US Facilities | 0 | 0 | 0 | 0 | 0 | 0 | 15% | 0 | 0 |
| 1.3.1 | CDL Permanent Facilities | 0 | 0 | 0 | 0 | 0 | 600 | 0% | 600 | 600 |
| 1.3.2 | Manufacturing Facilities | 0 | 0 | 0 | 0 | 0 | 115 | 10% | 127 | 140 |
| 1.3.3 | Common Infrastructure | 0 | 0 | 0 | 0 | 0 | 200 | 15% | 230 | 254 |
| | | | | | | | | | | |
| 2 | Site Development | 0 | 0 | 12 | 0 | 87 | 50 | 5% | 144 | 159 |
| 2.2 | Maintain Mining claims | 0 | 0 | 0 | 0 | 0 | 25 | 5% | 26 | 29 |
| 2.3 | Contract A&E Studies | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 2.5.3 | Contract Array Site Civil Works | 0 | 0 | 0 | 0 | 0 | 5,408 | 20% | 6,490 | 7,163 |
| 2.6.3 | Contract OSF Civil Works | 0 | 0 | 0 | 0 | 0 | 3,535 | 20% | 4,242 | 4,682 |
| 2.7.3 | Contract Civil Works | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 2.8.1 | Equip Array Site | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 2.8.2 | Equip Operations Support Facility | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| | | | | | | | | | | |
| 3.1 | Antenna Engineering Support | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 3.8.10 | Sign Transporter Contract | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 3.8.30 | Accept Transporter #2 at OSF | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 3.8.35 | Contract for Transporter #1 Move to site | 0 | 0 | 0 | 0 | 0 | 0 | 12% | 0 | 0 |
| 3.15 | Procurement of Antenna 2 | 0 | 0 | 0 | 0 | 0 | 0 | 27% | 0 | 0 |
| 3.20 | Sign Contract for Production Antennas | 0 | 0 | 0 | 0 | 0 | 1,615 | 20% | 1,938 | 2,139 |
| 3.21 | Antenna Contract Supervision | 0 | 0 | 12 | 0 | 87 | 0 | 12% | 98 | 108 |
| 3.23 | Accept Antenna #3 at OSF | 0 | 0 | 0 | 0 | 0 | 2,754 | 27% | 3,498 | 3,861 |
| 3.25, 3.27, 3.2 | Accept Antennas #4 through #36 | 0 | 0 | 0 | 0 | 0 | 0 | 27% | 0 | 0 |
| | | | | | | | | | | |
| 4.1.1.2 | Fabricate PPRC | 0 | 0 | 0 | 0 | 0 | 0 | 28% | 0 | 0 |
| 4.1.1.3 | Test PPRC | 0 | 0 | 0 | 0 | 0 | 0 | 5% | 0 | 0 |
| 4.1.2.1 | PPR Dewar Design | 0 | 0 | 0 | 0 | 0 | 0 | 17% | 0 | 0 |
| 4.1.2.2 | PPR Dewar Fabrication and Vacuum Testing | 0 | 0 | 0 | 0 | 0 | 0 | 40% | 0 | 0 |
| 4.1.2.3 | PPR Vacuum Windows and IR Filters | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 4.1.2.4 | PPR Cryogenics/Dewar Assembly and Testing | 0 | 0 | 0 | 0 | 0 | 0 | 13% | 0 | 0 |
| 4.1.3.1 | PPR Control-Monitoring and Bias Electronics Design | 0 | 0 | 0 | 0 | 0 | 0 | 21% | 0 | 0 |
| 4.1.3.2 | PPR Control-Monitor and Bias Electronics Construction | 0 | 0 | 0 | 0 | 0 | 0 | 44% | 0 | 0 |
| 4.1.4.1 | Insert Mechanical-Thermal Design, Bands <275 GHz (Waveguide | 0 | 0 | 0 | 0 | 0 | 0 | 48% | 0 | 0 |
| 4.1.4.2 | Insert Component Fabrication for Bands <275 GHz | 0 | 0 | 0 | 0 | 0 | 0 | 56% | 0 | 0 |
| 4.1.4.3 | Insert Mechanical-Thermal Design for Bands >275 GHz (Quasi o | 0 | 0 | 0 | 0 | 0 | 0 | 48% | 0 | 0 |
| 4.1.4.4 | Insert Component Fabrication for Bands >275 Ghz | 0 | 0 | 0 | 0 | 0 | 0 | 56% | 0 | 0 |
| 4.1.4.8 | PPR Insert Assembly (3 Bands) | 0 | 0 | 0 | 0 | 0 | 0 | 44% | 0 | 0 |
| 4.1.4.9 | PPR Insert Testing (3 Bands) | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.1.5.1 | PPR Vacuum System Assembly | 0 | 0 | 0 | 0 | 0 | 0 | 8% | 0 | 0 |
| 4.1.7.1 | PPR Post IF System Design | 0 | 0 | 0 | 0 | 0 | 0 | 22% | 0 | 0 |

# Millimeter Array Construction: 2003

US Reference Project

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|---|---|---|---|---|---|---|---|---|---|---|
| 4.1.7.2 | PPR Post IF System Construction and Testing | 0 | 0 | 0 | 0 | 0 | 0 | 24% | 0 | 0 |
| 4.1.8.1 | PPR Frame Design | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.1.8.2 | PPR Frame Fabrication | 0 | 0 | 0 | 0 | 0 | 0 | 30% | 0 | 0 |
| 4.1.9.1 | Prototype Production Receiver Integration | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.1.9.2 | PPR Testing and Evaluation | 0 | 0 | 0 | 0 | 0 | 0 | 36% | 0 | 0 |
| 4.1.10.1 | Design and build Prototype and Production Receiver Test Set | 0 | 0 | 0 | 0 | 0 | 0 | 36% | 0 | 0 |
| 4.1.10.2 | Design and Fabricate Receiver Insert Test Set | 0 | 0 | 0 | 0 | 0 | 0 | 11% | 0 | 0 |
| 4.1.10.3 | General Test Equipment | 0 | 0 | 0 | 0 | 0 | 0 | 13% | 0 | 0 |
| 4.2.1 | MMA Receiver (MMA Rx) Design Refinement | 0 | 0 | 0 | 0 | 0 | 0 | 28% | 0 | 0 |
| 4.2.2 | MMA Receiver (MMA Rx) Documentation | 0 | 0 | 0 | 0 | 0 | 0 | 18% | 0 | 0 |
| 4.2.4.1 | MMA Rx Dewar Fabrication | 0 | 0 | 1 | 6 | 31 | 42 | 16% | 84 | 93 |
| 4.2.4.2 | MMA Rx Cryogenics Fabrication | 0 | 0 | 2 | 18 | 85 | 396 | 20% | 577 | 637 |
| 4.2.4.3 | Vacuum Windows and IR Filters Fabrication | 0 | 0 | 2 | 11 | 57 | 91 | 16% | 172 | 190 |
| 4.2.4.4 | Receiver Insert Fabrication | 0 | 0 | 2 | 68 | 280 | 603 | 22% | 1,077 | 1,189 |
| 4.2.4.5 | MMA Receiver Frame Fabrication and assembly | 0 | 0 | 1 | 12 | 54 | 90 | 16% | 167 | 184 |
| 4.2.4.6 | Vacuum System Fabrication and testing. | 0 | 0 | 0 | 6 | 23 | 180 | 16% | 236 | 260 |
| 4.2.4.7 | Bias and Control-Monitoring Electronics Construction | 0 | 0 | 1 | 4 | 23 | 216 | 16% | 277 | 306 |
| 4.2.4.9 | Assemble Receiver Inserts and Test | 0 | 0 | 34 | 68 | 512 | 657 | 20% | 1,403 | 1,548 |
| 4.2.4.10 | Assemble MMA Rx IF System | 0 | 0 | 1 | 4 | 23 | 87 | 14% | 125 | 138 |
| 4.2.6.1 | Integrate Test & Commission MMA Receivers | 0 | 0 | 9 | 18 | 136 | 18 | 16% | 178 | 197 |
| 4.5.1 | Construct and test Cryo system for 2nd Evaluation Receiver | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.5.2 | Fabrication and assembly of 2nd Evaluation Receiver. | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.5.3 | Test and Commission 2nd Evaluation Receiver | 0 | 0 | 0 | 0 | 0 | 0 | 5% | 0 | 0 |
| 4.3.1.1 | Design, Fab, and Test 211-275 GHz Mixer Design | 0 | 0 | 0 | 0 | 0 | 0 | 52% | 0 | 0 |
| 4.3.1.3 | Fabricate 211-275 GHz mixer blocks | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.3.1.4 | Fabricate & test 211-275 GHz SIS Mixer Detector Modules | 0 | 0 | 0 | 0 | 0 | 0 | 52% | 0 | 0 |
| 4.3.2.1 | Design, Fab, and Test 602-720 GHz Mixer Design | 0 | 0 | 0 | 0 | 0 | 0 | 52% | 0 | 0 |
| 4.3.2.3 | Fabricate 602-720 GHz mixer blocks | 0 | 0 | 0 | 7 | 27 | 11 | 16% | 45 | 49 |
| 4.3.2.4 | Fabricate & test 602-720 GHz SIS Mixer Detector Modules | 0 | 0 | 9 | 22 | 151 | 119 | 78% | 481 | 531 |
| 4.3.3.1 | Design, Fab, and Test 275-370 GHz Mixer Design | 0 | 0 | 0 | 0 | 0 | 0 | 52% | 0 | 0 |
| 4.3.3.3 | Fabricate 275-370 GHz mixer blocks | 0 | 0 | 0 | 5 | 20 | 3 | 16% | 26 | 28 |
| 4.3.3.4 | Fabricate & test 275-370 GHz SIS Mixer Detector Modules | 0 | 0 | 6 | 14 | 98 | 174 | 52% | 414 | 457 |
| 4.3.4.1 | Design, Fab, and Test 89-116 GHz Mixer Design | 0 | 0 | 16 | 19 | 190 | 327 | 52% | 786 | 868 |
| 4.3.4.3 | Fabricate 89-116 GHz mixer blocks | 0 | 0 | 0 | 3 | 12 | 3 | 16% | 16 | 18 |
| 4.3.4.4 | Fabricate 89-116 GHz SIS Mixer Detector Modules | 0 | 0 | 6 | 14 | 98 | 202 | 52% | 456 | 504 |
| 4.3.5.1 | Design, Fab, and Test 163-211 GHz Mixer Design | 0 | 0 | 32 | 39 | 384 | 117 | 52% | 762 | 841 |
| 4.3.5.3 | Fabricate 163-211 GHz Mixer Blocks | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.3.5.4 | Fabricate & test 163-211 GHz SIS Mixer Detector Modules | 0 | 0 | 0 | 0 | 0 | 0 | 52% | 0 | 0 |
| 4.3.6.1 | Design, Fab, and Test 385-500 GHz Mixer Design | 0 | 0 | 20 | 20 | 223 | 117 | 52% | 517 | 571 |
| 4.3.6.3 | Fabricate 385-500 GHz mixer blocks | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.3.6.4 | Fabricate & Test 385-500 GHz SIS Mixer Detector Modules | 0 | 0 | 0 | 0 | 0 | 0 | 52% | 0 | 0 |
| 4.3.7.1 | Design, Fab, and Test 125-163 GHz Mixer Design | 0 | 0 | 0 | 0 | 0 | 0 | 52% | 0 | 0 |
| 4.3.7.3 | Fabricate 125-163 GHz mixer blocks | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.3.7.4 | Fabricate & Test 125-163 GHz SIS Mixer Detector Modules | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 4.3.8.1 | Build SIS Fabrication Equipment | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.3.8.2 | Build SIS Test Dewar & Rack #1 | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.3.8.3 | Build SIS Test Dewar & Rack #2 | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.3.8.4 | Build SIS Test Dewar & Rack #3 | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.3.8.5 | Build SIS Test Dewar & Rack #4 | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.3.8.6 | Build Wafer Evaluation Test Sets | 0 | 0 | 0 | 0 | 0 | 0 | 18% | 0 | 0 |
| 4.3.8.7.1 | General SIS Test Equipment | 0 | 0 | 0 | 0 | 0 | 0 | 5% | 0 | 0 |
| 4.3.8.7.2 | Equip Network Analyzer to 330 GHz | 0 | 0 | 2 | 0 | 15 | 109 | 15% | 142 | 157 |

# Millimeter Array Construction: 2003

US Reference Project

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|---|---|---|---|---|---|---|---|---|---|---|
| 4.3.8.7.3 | Near-Field Antenna Test Equipment | 0 | 0 | 0 | 0 | 0 | 30 | 15% | 34 | 37 |
| 4.3.8.8 | Build 211-275 GHz Test Plates | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.3.8.9 | Build 602-720 GHz Test Plates | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.3.8.10 | Build 275-370 GHz Test Plates | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.3.8.11 | Build 89-116 GHz Test Plates | 0 | 0 | 6 | 6 | 67 | 220 | 14% | 327 | 361 |
| 4.3.8.12 | Build 163-211 GHz Test Plates | 0 | 0 | 6 | 6 | 67 | 240 | 14% | 350 | 386 |
| 4.3.8.13 | Build 385-500 GHz Test Plates | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.3.8.14 | Build 125-163 GHz Test Plates | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.3.9.1 | Obtain and evaluate InP IF amplifier wafers | 0 | 0 | 0 | 0 | 0 | 0 | 10% | 0 | 0 |
| 4.3.9.2 | Build IF amplifiers | 0 | 0 | 6 | 32 | 168 | 104 | 10% | 300 | 331 |
| 4.4.1 | Contract for HFET wafer | 0 | 0 | 0 | 0 | 0 | 0 | 24% | 0 | 0 |
| 4.4.2 | Receive and evaluate InP LNA wafer | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.4.3.1 | Build 31-45 GHz HFET Detector Modules | 0 | 0 | 0 | 0 | 0 | 0 | 10% | 0 | 0 |
| 4.4.4.1 | Design 67-90 GHz amplifier | 0 | 0 | 0 | 0 | 0 | 0 | 26% | 0 | 0 |
| 4.4.4.2 | Build 67-90 GHz HFET Detector Modules | 0 | 0 | 6 | 18 | 114 | 0 | 14% | 130 | 143 |
| | | | | | | | | | | |
| 5.1 | LO Reference: Prototype Systems | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 5.2.1 | Production test and lab equipment | 0 | 0 | 0 | 0 | 0 | 0 | 10% | 0 | 0 |
| 5.2.2 | H-maser Frequency Standard (& Rb) | 0 | 0 | 1 | 1 | 11 | 0 | 8% | 12 | 13 |
| 5.2.3 | 8 GHz PL Oscillator & Distributor | 0 | 0 | 1 | 2 | 15 | 36 | 12% | 57 | 63 |
| 5.2.4 | 10 GHz PL Oscillator & Distributor | 0 | 0 | 1 | 2 | 15 | 36 | 12% | 57 | 63 |
| 5.2.5 | 12 GHz PL Oscillator & Distributor | 0 | 0 | 1 | 2 | 15 | 36 | 12% | 57 | 63 |
| 5.2.6 | 14 GHz PL Oscillator & Distributor | 0 | 0 | 1 | 2 | 15 | 36 | 12% | 57 | 63 |
| 5.2.7 | 3.2-5.2 GHz Synthesizer | 0 | 0 | 2 | 12 | 61 | 336 | 16% | 461 | 509 |
| 5.2.8 | 3.2 -5.2 GHz PLO and Fringe Generator | 0 | 0 | 1 | 6 | 31 | 118 | 14% | 169 | 187 |
| 5.2.9 | Sampler Clock 4 GHz PL Osc & Distributor | 0 | 0 | 1 | 3 | 19 | 36 | 12% | 61 | 68 |
| 5.2.10 | LO Ref Generator | 0 | 0 | 0 | 0 | 0 | 0 | 12% | 0 | 0 |
| 5.2.11 | LO Ref Distributor - Control Bldg | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 5.2.12 | Microwave Round-trip Phase Measurement | 0 | 0 | 3 | 3 | 33 | 108 | 49% | 211 | 233 |
| 5.2.13 | 10-15 GHz Frequency Synthesizer | 0 | 0 | 1 | 6 | 31 | 71 | 49% | 151 | 167 |
| 5.2.14 | First LO Fringe Generator | 0 | 0 | 1 | 6 | 31 | 118 | 16% | 172 | 190 |
| 5.2.15 | 16 GHz PL Oscillator & Distributor | 0 | 0 | 1 | 2 | 15 | 36 | 12% | 57 | 63 |
| 5.2.16 | 26 GHz PL Oscillator & Distributor | 0 | 0 | 1 | 2 | 15 | 36 | 12% | 57 | 63 |
| 5.2.17 | LO Ref Distributor - Antenna | 0 | 0 | 0 | 2 | 8 | 48 | 18% | 65 | 72 |
| 5.2.18 | VXCO Clean-up Loop | 0 | 0 | 1 | 2 | 15 | 106 | 100% | 243 | 268 |
| 5.2.19 | Power supply module | 0 | 0 | 1 | 1 | 11 | 19 | 5% | 32 | 35 |
| 5.2.20 | Bins / Racks (assemble and test) | 0 | 0 | 0 | 0 | 0 | 11 | 14% | 13 | 14 |
| 5.3.1 | LO Source Design and System Integration | 0 | 0 | 12 | 18 | 157 | 20 | 36% | 241 | 266 |
| 5.3.2.1 | 72-95 GHz LO Source Procurement & Fabrication | 0 | 0 | 1 | 10 | 46 | 86 | 24% | 164 | 181 |
| 5.3.2.2 | 72-95 GHz LO Source Assembly & Test | 0 | 0 | 1 | 2 | 15 | 2 | 24% | 21 | 23 |
| 5.3.3.1 | 102-120 GHz LO Source Procurement & Fabrication | 0 | 0 | 1 | 10 | 46 | 115 | 24% | 199 | 220 |
| 5.3.3.2 | 102-120 GHz LO Source Assembly & Test | 0 | 0 | 1 | 2 | 15 | 2 | 24% | 22 | 24 |
| 5.3.4.1 | 87-108 GHz LO Source Procurement & Fabrication | 0 | 0 | 2 | 12 | 61 | 229 | 24% | 360 | 398 |
| 5.3.4.2 | 87-108 GHz LO Source Assembly & Test | 0 | 0 | 3 | 3 | 33 | 5 | 24% | 48 | 53 |
| 5.3.5.1 | 65-86 GHz LO Source Procurement & Fabrication | 0 | 0 | 2 | 12 | 61 | 229 | 24% | 360 | 398 |
| 5.3.5.2 | 65-86 GHz LO Source Assembly & Test | 0 | 0 | 3 | 3 | 33 | 5 | 24% | 48 | 53 |
| 5.4.1 | LO Multiplier Chain Design & System Integration | 0 | 0 | 18 | 18 | 201 | 335 | 36% | 729 | 804 |
| 5.4.2.1 | 211-275 GHz Receiver LO multiplier Parts | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.2.2 | 211-275 GHz Receiver LO Multiplier Assembly & Test | 0 | 0 | 1 | 7 | 35 | 0 | 34% | 46 | 51 |
| 5.4.2.3 | 275-370 GHz LO integrate source & multiplier | 0 | 0 | 3 | 8 | 53 | 10 | 34% | 84 | 93 |
| 5.4.3.1 | 602-720 GHz Receiver LO multiplier Parts | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.3.2 | 602-720 GHz Receiver LO multiplier Assembly & Test | 0 | 0 | 2 | 12 | 61 | 0 | 34% | 82 | 91 |

# Millimeter Array Construction: 2003

US Reference Project

| WBS | Task Name | Scientists Work-months | Programmers Work-months | Engineers Work-months | Technicians Work-months | Personnel 1999 $K | Materials & Supplies 1999 $K | Contingency | Total Cost 1999 $K | Inflated Cost 2003 $K |
|---|---|---|---|---|---|---|---|---|---|---|
| 5.4.3.3 | 602-720 GHz LO integrate source & multiplier | 0 | 0 | 4 | 12 | 76 | 20 | 34% | 128 | 142 |
| 5.4.4.1 | 275-370 GHz Receiver LO multiplier Parts | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.4.2 | 275-370 GHz Receiver LO multiplier Assembly & Test | 0 | 0 | 2 | 9 | 50 | 0 | 34% | 66 | 73 |
| 5.4.4.3 | 275-370 GHz LO integrate source & multiplier | 0 | 0 | 4 | 12 | 76 | 20 | 34% | 128 | 142 |
| 5.4.5.1 | 163-211 GHz Receiver LO multiplier Parts | 0 | 0 | 1 | 5 | 27 | 30 | 34% | 77 | 85 |
| 5.4.5.2 | 163-211 GHz Receiver LO multiplier Assembly & Test | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.5.3 | 163-211 GHz LO integrate source & multiplier | 0 | 0 | 3 | 8 | 53 | 10 | 34% | 84 | 93 |
| 5.4.6.1 | 385-500 GHz Receiver LO multiplier Parts | 0 | 0 | 2 | 8 | 46 | 61 | 34% | 143 | 158 |
| 5.4.6.2 | 385-500 GHz Receiver LO multiplier Assembly & Test | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.6.3 | 385-500 GHz LO integrate source & multiplier | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.7.1 | 125-163 GHz Receiver LO multiplier Parts | 0 | 0 | 1 | 3 | 15 | 24 | 34% | 53 | 58 |
| 5.4.7.2 | 125-163 GHz Receiver LO multiplier Assembly & Test | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.7.3 | 125-163 GHz LO integrate source & multiplier | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.8.1 | Design & fab 31-45 GHz receiver LO coupling | 0 | 0 | 0 | 0 | 0 | 0 | 12% | 0 | 0 |
| 5.4.9 | LO Multiplier Fabrication Equipment | 0 | 0 | 0 | 0 | 0 | 0 | 11% | 0 | 0 |
| 5.4.10 | LO Multiplier Test Equipment | 0 | 0 | 0 | 0 | 0 | 0 | 11% | 0 | 0 |
| | | | | | | | | | | |
| 6.1 | IF Field Prototype for Test Interferometer of 2 antennas. | 0 | 0 | 2 | 3 | 26 | 0 | 10% | 29 | 32 |
| 6.2 | IF Construction test & lab equipment | 0 | 0 | 1 | 2 | 15 | 0 | 5% | 16 | 17 |
| 6.3 | IF Multiplexer (2/antenna) | 0 | 0 | 6 | 11 | 86 | 506 | 20% | 710 | 784 |
| 6.4 | IF Demultiplexer (2/antenna) | 0 | 0 | 5 | 11 | 79 | 179 | 10% | 284 | 313 |
| 6.5 | IF Matrix Switch (2/antenna) | 0 | 0 | 2 | 6 | 38 | 111 | 6% | 158 | 174 |
| 6.6 | IF Baseband Converter (8/antenna) | 0 | 0 | 6 | 11 | 86 | 430 | 20% | 620 | 684 |
| 6.7 | IF Power Supply module | 0 | 0 | 1 | 1 | 11 | 14 | 5% | 27 | 29 |
| 6.8 | Bins / Racks (assemble and test) | 0 | 0 | 1 | 3 | 19 | 33 | 5% | 54 | 60 |
| | | | | | | | | | | |
| 7.1 | Prototype Optical Fiber Systems | 0 | 0 | 7 | 14 | 105 | 0 | 32% | 139 | 154 |
| 7.2 | Digital IF Transmitters and Receivers | 0 | 0 | 18 | 27 | 236 | 808 | 40% | 1,461 | 1,613 |
| 7.3.1 | 16 GHZ FO LO Ref Dist Prototype | 0 | 0 | 9 | 18 | 136 | 0 | 40% | 190 | 209 |
| 7.3.2 | 16 GHz FO LO Ref Dist with Integrated R/T Phase Meas. | 0 | 0 | 24 | 12 | 221 | 139 | 28% | 460 | 508 |
| 7.4 | Production Test Equipment | 0 | 0 | 0 | 0 | 0 | 0 | 5% | 0 | 0 |
| 7.5 | Monitor and Control Transmitters and Receivers | 0 | 0 | 5 | 12 | 83 | 47 | 14% | 148 | 163 |
| 7.6 | Fiber Optics Power Supply Modules | 0 | 0 | 2 | 4 | 30 | 16 | 14% | 53 | 59 |
| 7.7 | Bins / Racks (assemble and test) | 0 | 0 | 5 | 8 | 67 | 20 | 14% | 99 | 110 |
| | | | | | | | | | | |
| 8.1.1 | Refine digitizer design | 0 | 0 | 0 | 0 | 0 | 0 | 30% | 0 | 0 |
| 8.1.3 | Digitizer contract materials | 0 | 0 | 0 | 0 | 0 | 0 | 30% | 0 | 0 |
| 8.1.4 | Assembly of digitizers | 0 | 0 | 0 | 0 | 0 | 0 | 26% | 0 | 0 |
| 8.1.5 | Digitizer validation and delivery | 0 | 0 | 4 | 3 | 41 | 5 | 26% | 58 | 64 |
| 8.2.1 | Prototype FIR filter testing on interferometer | 0 | 0 | 0 | 0 | 0 | 0 | 38% | 0 | 0 |
| 8.2.2 | Design & test FIR filter refinement | 0 | 0 | 0 | 0 | 0 | 0 | 32% | 0 | 0 |
| 8.2.4 | FIR filter chip & board fabrication | 0 | 0 | 0 | 0 | 0 | 0 | 32% | 0 | 0 |
| 8.2.5 | FIR filter board assembly | 0 | 0 | 1 | 6 | 31 | 5 | 26% | 45 | 50 |
| 8.2.6 | FIR filter board validation and delivery | 0 | 0 | 2 | 2 | 22 | 0 | 32% | 29 | 33 |
| 8.3.1 | Correlator boards | 0 | 0 | 0 | 0 | 0 | 0 | 26% | 0 | 0 |
| 8.4 | Correlator Chip | 0 | 0 | 0 | 0 | 0 | 0 | 30% | 0 | 0 |
| 8.6 | Correlator software | 0 | 12 | 0 | 0 | 72 | 2 | 20% | 88 | 97 |
| 8.5 | Correlator Racks | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 8.7 | Prototype Correlator Production | 0 | 0 | 18 | 18 | 201 | 104 | 28% | 390 | 431 |
| 8.8.1 | First 1/4 Correlator | 0 | 0 | 18 | 18 | 201 | 389 | 28% | 755 | 833 |
| 8.8.2 | Second 1/4 Correlator | 0 | 0 | 0 | 0 | 0 | 389 | 24% | 482 | 532 |
| 8.8.3 | Third 1/4 Correlator | 0 | 0 | 0 | 0 | 0 | 0 | 24% | 0 | 0 |

# Millimeter Array Construction: 2003

US Reference Project

| WBS | Task Name | Scientists Work-months | Programmers Work-months | Engineers Work-months | Technicians Work-months | Personnel 1999 $K | Materials & Supplies 1999 $K | Contingency | Total Cost 1999 $K | Inflated Cost 2003 $K |
|---|---|---|---|---|---|---|---|---|---|---|
| 8.8.4 | Fourth 1/4 Correlator | 0 | 0 | 0 | 0 | 0 | 0 | 24% | 0 | 0 |
| 8.9 | Correlator test equipment | 0 | 0 | 0 | 0 | 0 | 0 | 5% | 0 | 0 |
| | | | | | | | | | | |
| 9 | Computing | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.1 | Control Software | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.1.1 | Test Interferometer Control and Analysis | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 9.1.2 | MMA Correlator Software | 3 | 36 | 0 | 0 | 236 | 0 | 34% | 316 | 349 |
| 9.1.3 | Multi-antenna & sub-array control | 0 | 24 | 0 | 0 | 143 | 0 | 34% | 192 | 212 |
| 9.1.4 | Operators and Observers Interfaces | 0 | 18 | 0 | 0 | 107 | 0 | 34% | 144 | 159 |
| 9.1.5 | Deliver control software | 0 | 0 | 0 | 0 | 0 | 0 | 30% | 0 | 0 |
| 9.1.6 | Maintenance | 0 | 0 | 0 | 0 | 0 | 0 | 18% | 0 | 0 |
| 9.2 | Scheduling | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.2.1 | Static Scheduling System | 0 | 9 | 0 | 0 | 54 | 0 | 34% | 72 | 79 |
| 9.2.2 | Dynamic scheduling simulations | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 9.2.3 | Dynamic scheduling prototype | 0 | 0 | 0 | 0 | 0 | 0 | 30% | 0 | 0 |
| 9.2.4 | Dynamic scheduling implementation | 0 | 0 | 0 | 0 | 0 | 0 | 39% | 0 | 0 |
| 9.3 | Proposal preparation software | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.3.1 | Proposal assistance prototype | 0 | 0 | 0 | 0 | 0 | 0 | 30% | 0 | 0 |
| 9.3.2 | Proposal assistance implementation | 0 | 0 | 0 | 0 | 0 | 0 | 30% | 0 | 0 |
| 9.3.3 | Observe program prototype | 3 | 3 | 0 | 0 | 39 | 0 | 26% | 50 | 55 |
| 9.3.4 | Observe program | 0 | 0 | 0 | 0 | 0 | 0 | 26% | 0 | 0 |
| 9.4 | Image pipeline | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.4.1 | Automated calibration & imaging heuristics | 6 | 0 | 0 | 0 | 43 | 0 | 39% | 60 | 66 |
| 9.4.2 | Prototype image pipeline | 0 | 0 | 0 | 0 | 0 | 0 | 30% | 0 | 0 |
| 9.4.3 | Parallelization studies and implementation | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 9.4.4 | Initial image pipeline operations | 0 | 0 | 0 | 0 | 0 | 0 | 26% | 0 | 0 |
| 9.4.5 | Production image pipeline | 0 | 0 | 0 | 0 | 0 | 0 | 30% | 0 | 0 |
| 9.5 | Archiving | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.5.1 | Prototype distributed archive | 6 | 6 | 0 | 0 | 79 | 21 | 30% | 130 | 143 |
| 9.5.2 | Evaluate storage hardware | 0 | 0 | 0 | 0 | 0 | 0 | 11% | 0 | 0 |
| 9.5.3 | Production archive | 0 | 0 | 0 | 0 | 0 | 0 | 30% | 0 | 0 |
| 9.6 | Post processing | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.6.1 | Define data formats | 0 | 0 | 0 | 0 | 0 | 0 | 18% | 0 | 0 |
| 9.6.2 | Filler and format conversions | 0 | 0 | 0 | 0 | 0 | 0 | 22% | 0 | 0 |
| 9.6.3 | ALMA specific calibrations | 3 | 0 | 0 | 0 | 21 | 0 | 39% | 30 | 33 |
| 9.6.4 | MMA Post-processing begins | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.6.5 | Maintenance | 0 | 0 | 0 | 0 | 0 | 0 | 22% | 0 | 0 |
| 9.7 | Software support | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.7.1 | Tool support | 0 | 6 | 0 | 0 | 36 | 0 | 34% | 48 | 53 |
| 9.7.2 | Quality assurance | 0 | 12 | 0 | 0 | 72 | 0 | 34% | 96 | 106 |
| 9.7.3 | Chile system administration | 0 | 0 | 0 | 0 | 0 | 0 | 22% | 0 | 0 |
| | | | | | | | | | | |
| 10 | System Integration | 0 | 0 | 0 | 0 | 0 | 0 | 10% | 0 | 0 |
| 10.4 | Test Interferometer Site Preparation | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.10 | Oufitting at U.S. test site | 0 | 0 | 0 | 0 | 0 | 0 | 12% | 0 | 0 |
| 10.10.4 | Antenna #1 Outfitting | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.10.7 | Antenna #2 Outfitting | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.10.10 | General Outfitting | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.11 | Single Dish Tests | 0 | 0 | 0 | 0 | 0 | 0 | 11% | 0 | 0 |
| 10.11.1 | Ant #1 holography and surface readjustment | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.11.2 | Ant #1 Antenna Evaluation | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.11.6 | Ant #2 holography and surface readjustment | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |

# Millimeter Array Construction: 2003

US Reference Project

| WBS | Task Name | Scientists Work-months | Programmers Work-months | Engineers Work-months | Technicians Work-months | Personnel 1999 $K | Materials & Supplies 1999 $K | Contingency | Total Cost 1999 $K | Inflated Cost 2003 $K |
|---|---|---|---|---|---|---|---|---|---|---|
| 10.11.7 | Ant #2 Antenna Evaluation | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.12 | Interferometric Tests | 0 | 0 | 0 | 0 | 0 | 0 | 11% | 0 | 0 |
| 10.12.1 | Phase/gain stability tests | 4 | 1 | 1 | 1 | 46 | 0 | 25% | 57 | 63 |
| 10.12.2 | Sensitivity verification | 2 | 1 | 1 | 0 | 28 | 0 | 25% | 34 | 38 |
| 10.12.3 | Holography with astronomical sources | 4 | 2 | 1 | 1 | 52 | 0 | 25% | 65 | 71 |
| 10.12.4 | Modifications and Retrofits | 0 | 0 | 0 | 0 | 0 | 0 | 35% | 0 | 0 |
| 10.13 | Dissassemble test system and ship to array site | 0 | 0 | 0 | 0 | 0 | 0 | 35% | 0 | 0 |
| 10.14 | On-site System Integration | 0 | 0 | 0 | 0 | 0 | 0 | 50% | 0 | 0 |
| 10.14.1 | Set up assembly and test facilities at OSF | 0 | 0 | 1 | 2 | 15 | 0 | 25% | 19 | 21 |
| 10.14.2 | Outfit antennas 3 through 36 | 0 | 0 | 0 | 0 | 0 | 10 | 25% | 13 | 14 |
| 10.14.2.1 | Wiring and plumbing | 0 | 0 | 0 | 7 | 29 | 77 | 25% | 132 | 146 |
| 10.14.2.2 | Install electronics in receiver cabin | 0 | 0 | 0 | 7 | 25 | 77 | 25% | 128 | 141 |
| 10.14.2.3 | Check out completed antenna at OSF | 2 | 0 | 7 | 7 | 84 | 0 | 25% | 105 | 116 |
| 10.14.2.4 | Install antenna at array site. | 0 | 0 | 0 | 7 | 28 | 0 | 25% | 36 | 39 |
| 10.14.3 | Refurbish antennas 1 and 2 | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.14.3.1 | Re-install electronics and upgrade as needed | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.14.3.2 | Check out at OSF | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.14.3.3 | Install antenna at array site | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.14.4 | Install central building electronics | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.14.5 | Support debugging and repair | 0 | 0 | 6 | 12 | 90 | 0 | 25% | 113 | 125 |
| 10.20 | Prototype Testing Support | 0 | 0 | 1 | 1 | 11 | 10 | 10% | 23 | 26 |
| | | | | | | | | | | |
| 11.1.1 | Completion of 183 GHz Water Vapor Radiometer | 0 | 0 | 0 | 0 | 0 | 0 | 11% | 0 | 0 |
| 11.1.2 | Demonstrate 183 GHz Water Vapor Radiometer | 0 | 0 | 0 | 0 | 0 | 0 | 12% | 0 | 0 |
| 11.1.3 | Refinement of 183 GHz Water Vapor Radiometer | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 11.1.4 | Release WVR for manufacture | 0 | 0 | 0 | 0 | 0 | 0 | 10% | 0 | 0 |
| 11.2.1.1 | Contract Phase Monitor Radiometer Subassembly | 0 | 0 | 0 | 0 | 0 | 90 | 10% | 99 | 109 |
| 11.2.1.2 | WVR Spectrometer | 0 | 0 | 0 | 0 | 0 | 75 | 10% | 83 | 91 |
| 11.2.1.3 | WVR Feed, Window, Lens, Instrumentation | 0 | 0 | 0 | 0 | 0 | 60 | 10% | 66 | 73 |
| 11.2.1.4 | Monitor and Control WVR Interface | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 11.2.3 | Deliver Production Radiometers | 0 | 0 | 0 | 6 | 23 | 7 | 9% | 33 | 37 |
| 11.2.4 | Integration of WVR into Receiver Package | 0 | 0 | 0 | 6 | 23 | 0 | 7% | 25 | 28 |
| 11.2.5 | Verification on Site of WVR | 0 | 0 | 0 | 0 | 0 | 0 | 9% | 0 | 0 |
| 11.3.1 | Dual-Load Amp. Calibration Device Design Refinement | 0 | 0 | 0 | 0 | 0 | 0 | 7% | 0 | 0 |
| 11.3.2 | Release Dual-Load Amp Cal for Mftr | 0 | 0 | 0 | 0 | 0 | 0 | 8% | 0 | 0 |
| 11.3.3 | Contract Subassembly Dual-Load Amp Cal | 0 | 0 | 0 | 0 | 0 | 0 | 7% | 0 | 0 |
| 11.3.3.1 | Dual-Load AmpCal Subassy Machining | 0 | 0 | 0 | 1 | 4 | 19 | 7% | 24 | 27 |
| 11.3.3.2 | Load Fabrication for Dual Load Amp Cal | 0 | 0 | 0 | 4 | 16 | 24 | 7% | 42 | 47 |
| 11.3.3.3 | Dual Load Amplitude Calibration Device Motors, Servo | 0 | 0 | 0 | 4 | 16 | 24 | 7% | 42 | 47 |
| 11.3.3.4 | M/C Interface for Dual Load Amp Cal Device | 0 | 0 | 0 | 4 | 16 | 28 | 7% | 47 | 51 |
| 11.3.4 | Assembly and Test of Dual Load Amplitude Calibration | 0 | 0 | 0 | 4 | 16 | 0 | 7% | 17 | 18 |
| 11.3.5 | Integration of AmpCal on Production Antennas | 0 | 0 | 0 | 0 | 0 | 0 | 7% | 0 | 0 |
| 11.4 | Imaging Studies and Project Support | 0 | 0 | 0 | 0 | 0 | 0 | 5% | 0 | 0 |
| 11.5 | Imaging Algorithm Development | 12 | 0 | 0 | 0 | 86 | 0 | 7% | 92 | 101 |
| | | | | | | | | | | |
| | Totals | 105 | 130 | 455 | 948 | 8,521 | 25,646 | | 42,317 | 46,648 |

# Millimeter Array Construction: 2004

US Reference Project

| WBS | Task Name | Scientists Work-months | Programmers Work-months | Engineers Work-months | Technicians Work-months | Personnel 1999 $K | Materials & Supplies 1999 $K | Contingency | Total Cost 1999 $K | Inflated Cost 2004 $K |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.1 | Project Management | 60 | 0 | 0 | 24 | 523 | 0 | 15% | 601 | 680 |
| 1.1.1 | Management, Planning, and Oversight | 0 | 0 | 0 | 0 | 0 | 705 | 15% | 811 | 917 |
| 1.1.2 | Business Operations | 0 | 0 | 0 | 0 | 0 | 100 | 15% | 115 | 130 |
| 1.1.3 | Chilean Operations | 0 | 0 | 0 | 0 | 0 | 15 | 15% | 17 | 20 |
| 1.1.4 | Safety and Health | 0 | 0 | 0 | 0 | 0 | 0 | 15% | 0 | 0 |
| 1.1.5 | Personnel | 0 | 0 | 0 | 0 | 0 | 0 | 15% | 0 | 0 |
| 1.1.6 | Project Science Office | 0 | 0 | 0 | 0 | 0 | 0 | 15% | 0 | 0 |
| 1.1.7 | AUI Management | 0 | 0 | 0 | 0 | 0 | 350 | 15% | 402 | 455 |
| 1.2 | Engineering | 0 | 0 | 24 | 12 | 221 | 20 | 15% | 277 | 314 |
| 1.2.1 | System Engineering--Phase II | 0 | 0 | 0 | 0 | 0 | 0 | 15% | 0 | 0 |
| 1.2.2 | Documentation System | 0 | 0 | 0 | 0 | 0 | 0 | 15% | 0 | 0 |
| 1.2.3 | Production Engineering | 0 | 0 | 0 | 0 | 0 | 0 | 15% | 0 | 0 |
| 1.3 | US Facilities | 0 | 0 | 0 | 0 | 0 | 0 | 15% | 0 | 0 |
| 1.3.1 | CDL Permanent Facilities | 0 | 0 | 0 | 0 | 0 | 600 | 0% | 600 | 600 |
| 1.3.2 | Manufacturing Facilities | 0 | 0 | 0 | 0 | 0 | 115 | 10% | 127 | 143 |
| 1.3.3 | Common Infrastructure | 0 | 0 | 0 | 0 | 0 | 200 | 15% | 230 | 260 |
| | | | | | | | | | | |
| 2 | Site Development | 0 | 0 | 12 | 0 | 87 | 50 | 5% | 144 | 163 |
| 2.2 | Maintain Mining claims | 0 | 0 | 0 | 0 | 0 | 25 | 5% | 26 | 30 |
| 2.3 | Contract A&E Studies | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 2.5.3 | Contract Array Site Civil Works | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 2.6.3 | Contract OSF Civil Works | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 2.7.3 | Contract Civil Works | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 2.8.1 | Equip Array Site | 0 | 0 | 0 | 0 | 0 | 400 | 20% | 480 | 543 |
| 2.8.2 | Equip Operations Support Facility | 0 | 0 | 0 | 0 | 0 | 2,200 | 20% | 2,640 | 2,987 |
| | | | | | | | | | | |
| 3.1 | Antenna Engineering Support | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 3.8.10 | Sign Transporter Contract | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 3.8.30 | Accept Transporter #2 at OSF | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 3.8.35 | Contract for Transporter #1 Move to site | 0 | 0 | 0 | 0 | 0 | 0 | 12% | 0 | 0 |
| 3.15 | Procurement of Antenna 2 | 0 | 0 | 0 | 0 | 0 | 0 | 27% | 0 | 0 |
| 3.20 | Sign Contract for Production Antennas | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 3.21 | Antenna Contract Supervision | 0 | 0 | 27 | 0 | 196 | 0 | 12% | 219 | 248 |
| 3.23 | Accept Antenna #3 at OSF | 0 | 0 | 2 | 0 | 11 | 0 | 27% | 14 | 16 |
| 3.25, 3.27, 3.2 | Accept Antennas #4 through #36 | 0 | 0 | 5 | 0 | 33 | 8,262 | 27% | 10,534 | 11,919 |
| | | | | | | | | | | |
| 4.1.1.2 | Fabricate PPRC | 0 | 0 | 0 | 0 | 0 | 0 | 28% | 0 | 0 |
| 4.1.1.3 | Test PPRC | 0 | 0 | 0 | 0 | 0 | 0 | 5% | 0 | 0 |
| 4.1.2.1 | PPR Dewar Design | 0 | 0 | 0 | 0 | 0 | 0 | 17% | 0 | 0 |
| 4.1.2.2 | PPR Dewar Fabrication and Vacuum Testing | 0 | 0 | 0 | 0 | 0 | 0 | 40% | 0 | 0 |
| 4.1.2.3 | PPR Vacuum Windows and IR Filters | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 4.1.2.4 | PPR Cryogenics/Dewar Assembly and Testing | 0 | 0 | 0 | 0 | 0 | 0 | 13% | 0 | 0 |
| 4.1.3.1 | PPR Control-Monitoring and Bias Electronics Design | 0 | 0 | 0 | 0 | 0 | 0 | 21% | 0 | 0 |
| 4.1.3.2 | PPR Control-Monitor and Bias Electronics Construction | 0 | 0 | 0 | 0 | 0 | 0 | 44% | 0 | 0 |
| 4.1.4.1 | Insert Mechanical-Thermal Design, Bands <275 GHz (Waveguid | 0 | 0 | 0 | 0 | 0 | 0 | 48% | 0 | 0 |
| 4.1.4.2 | Insert Component Fabrication for Bands <275 GHz | 0 | 0 | 0 | 0 | 0 | 0 | 56% | 0 | 0 |
| 4.1.4.3 | Insert Mechanical-Thermal Design for Bands >275 GHz (Quasi o | 0 | 0 | 0 | 0 | 0 | 0 | 48% | 0 | 0 |
| 4.1.4.4 | Insert Component Fabrication for Bands >275 Ghz | 0 | 0 | 0 | 0 | 0 | 0 | 56% | 0 | 0 |
| 4.1.4.8 | PPR Insert Assembly (3 Bands) | 0 | 0 | 0 | 0 | 0 | 0 | 44% | 0 | 0 |
| 4.1.4.9 | PPR Insert Testing (3 Bands) | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.1.5.1 | PPR Vacuum System Assembly | 0 | 0 | 0 | 0 | 0 | 0 | 8% | 0 | 0 |
| 4.1.7.1 | PPR Post IF System Design | 0 | 0 | 0 | 0 | 0 | 0 | 22% | 0 | 0 |

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| WBS | Task Name | Scientists Work-months | Programmers Work-months | Engineers Work-months | Technicians Work-months | Personnel 1999 $K | Materials & Supplies 1999 $K | Contingency | Total Cost 1999 $K | Inflated Cost 2004 $K |
|---|---|---|---|---|---|---|---|---|---|---|
| 4.1.7.2 | PPR Post IF System Construction and Testing | 0 | 0 | 0 | 0 | 0 | 0 | 24% | 0 | 0 |
| 4.1.8.1 | PPR Frame Design | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.1.8.2 | PPR Frame Fabrication | 0 | 0 | 0 | 0 | 0 | 0 | 30% | 0 | 0 |
| 4.1.9.1 | Prototype Production Receiver Integration | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.1.9.2 | PPR Testing and Evaluation | 0 | 0 | 0 | 0 | 0 | 0 | 36% | 0 | 0 |
| 4.1.10.1 | Design and build Prototype and Production Receiver Test Set | 0 | 0 | 0 | 0 | 0 | 0 | 36% | 0 | 0 |
| 4.1.10.2 | Design and Fabricate Receiver Insert Test Set | 0 | 0 | 0 | 0 | 0 | 0 | 11% | 0 | 0 |
| 4.1.10.3 | General Test Equipment | 0 | 0 | 0 | 0 | 0 | 0 | 13% | 0 | 0 |
| 4.2.1 | MMA Receiver (MMA Rx) Design Refinement | 0 | 0 | 0 | 0 | 0 | 0 | 28% | 0 | 0 |
| 4.2.2 | MMA Receiver (MMA Rx) Documentation | 0 | 0 | 0 | 0 | 0 | 0 | 18% | 0 | 0 |
| 4.2.4.1 | MMA Rx Dewar Fabrication | 0 | 0 | 1 | 10 | 46 | 70 | 16% | 135 | 153 |
| 4.2.4.2 | MMA Rx Cryogenics Fabrication | 0 | 0 | 3 | 30 | 139 | 660 | 20% | 959 | 1,084 |
| 4.2.4.3 | Vacuum Windows and IR Filters Fabrication | 0 | 0 | 2 | 11 | 57 | 91 | 16% | 172 | 195 |
| 4.2.4.4 | Receiver Insert Fabrication | 0 | 0 | 2 | 80 | 327 | 720 | 22% | 1,277 | 1,445 |
| 4.2.4.5 | MMA Receiver Frame Fabrication and assembly | 0 | 0 | 1 | 20 | 85 | 150 | 16% | 273 | 309 |
| 4.2.4.6 | Vacuum System Fabrication and testing. | 0 | 0 | 0 | 5 | 20 | 200 | 16% | 255 | 288 |
| 4.2.4.7 | Bias and Control-Monitoring Electronics Construction | 0 | 0 | 1 | 4 | 23 | 240 | 16% | 305 | 345 |
| 4.2.4.9 | Assemble Receiver Inserts and Test | 0 | 0 | 40 | 80 | 602 | 670 | 20% | 1,527 | 1,727 |
| 4.2.4.10 | Assemble MMA Rx IF System | 0 | 0 | 1 | 5 | 27 | 145 | 14% | 196 | 222 |
| 4.2.6.1 | Integrate Test & Commission MMA Receivers | 0 | 0 | 15 | 30 | 226 | 30 | 16% | 297 | 336 |
| 4.5.1 | Construct and test Cryo system for 2nd Evaluation Receiver | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.5.2 | Fabrication and assembly of 2nd Evaluation Receiver. | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.5.3 | Test and Commission 2nd Evaluation Receiver | 0 | 0 | 0 | 0 | 0 | 0 | 5% | 0 | 0 |
| 4.3.1.1 | Design, Fab, and Test 211-275 GHz Mixer Design | 0 | 0 | 0 | 0 | 0 | 0 | 52% | 0 | 0 |
| 4.3.1.3 | Fabricate 211-275 GHz mixer blocks | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.3.1.4 | Fabricate & test 211-275 GHz SIS Mixer Detector Modules | 0 | 0 | 0 | 0 | 0 | 0 | 52% | 0 | 0 |
| 4.3.2.1 | Design, Fab, and Test 602-720 GHz Mixer Design | 0 | 0 | 0 | 0 | 0 | 0 | 52% | 0 | 0 |
| 4.3.2.3 | Fabricate 602-720 GHz mixer blocks | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.3.2.4 | Fabricate & test 602-720 GHz SIS Mixer Detector Modules | 0 | 0 | 0 | 0 | 0 | 0 | 78% | 0 | 0 |
| 4.3.3.1 | Design, Fab, and Test 275-370 GHz Mixer Design | 0 | 0 | 0 | 0 | 0 | 0 | 52% | 0 | 0 |
| 4.3.3.3 | Fabricate 275-370 GHz mixer blocks | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.3.3.4 | Fabricate & test 275-370 GHz SIS Mixer Detector Modules | 0 | 0 | 0 | 0 | 0 | 0 | 52% | 0 | 0 |
| 4.3.4.1 | Design, Fab, and Test 89-116 GHz Mixer Design | 0 | 0 | 0 | 0 | 0 | 0 | 52% | 0 | 0 |
| 4.3.4.3 | Fabricate 89-116 GHz mixer blocks | 0 | 0 | 0 | 7 | 27 | 5 | 16% | 37 | 42 |
| 4.3.4.4 | Fabricate 89-116 GHz SIS Mixer Detector Modules | 0 | 0 | 12 | 30 | 204 | 356 | 52% | 852 | 964 |
| 4.3.5.1 | Design, Fab, and Test 163-211 GHz Mixer Design | 0 | 0 | 16 | 19 | 190 | 327 | 52% | 786 | 890 |
| 4.3.5.3 | Fabricate 163-211 GHz Mixer Blocks | 0 | 0 | 0 | 5 | 20 | 5 | 16% | 28 | 31 |
| 4.3.5.4 | Fabricate & test 163-211 GHz SIS Mixer Detector Modules | 0 | 0 | 8 | 20 | 136 | 293 | 52% | 652 | 738 |
| 4.3.6.1 | Design, Fab, and Test 385-500 GHz Mixer Design | 0 | 0 | 28 | 38 | 351 | 317 | 52% | 1,016 | 1,150 |
| 4.3.6.3 | Fabricate 385-500 GHz mixer blocks | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.3.6.4 | Fabricate & Test 385-500 GHz SIS Mixer Detector Modules | 0 | 0 | 0 | 0 | 0 | 0 | 52% | 0 | 0 |
| 4.3.7.1 | Design, Fab, and Test 125-163 GHz Mixer Design | 0 | 0 | 16 | 20 | 194 | 112 | 52% | 466 | 527 |
| 4.3.7.3 | Fabricate 125-163 GHz mixer blocks | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.3.7.4 | Fabricate & Test 125-163 GHz SIS Mixer Detector Modules | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 4.3.8.1 | Build SIS Fabrication Equipment | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.3.8.2 | Build SIS Test Dewar & Rack #1 | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.3.8.3 | Build SIS Test Dewar & Rack #2 | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.3.8.4 | Build SIS Test Dewar & Rack #3 | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.3.8.5 | Build SIS Test Dewar & Rack #4 | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.3.8.6 | Build Wafer Evaluation Test Sets | 0 | 0 | 0 | 0 | 0 | 0 | 18% | 0 | 0 |
| 4.3.8.7.1 | General SIS Test Equipment | 0 | 0 | 0 | 0 | 0 | 0 | 5% | 0 | 0 |
| 4.3.8.7.2 | Equip Network Analyzer to 330 GHz | 0 | 0 | 1 | 0 | 7 | 55 | 15% | 72 | 81 |

# Millimeter Array Construction: 2004

US Reference Project

| WBS | Task Name | Scientists Work-months | Programmers Work-months | Engineers Work-months | Technicians Work-months | Personnel 1999 $K | Materials & Supplies 1999 $K | Contingency | Total Cost 1999 $K | Inflated Cost 2004 $K |
|---|---|---|---|---|---|---|---|---|---|---|
| 4.3.8.7.3 | Near-Field Antenna Test Equipment | 0 | 0 | 0 | 0 | 0 | 0 | 15% | 0 | 0 |
| 4.3.8.8 | Build 211-275 GHz Test Plates | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.3.8.9 | Build 602-720 GHz Test Plates | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.3.8.10 | Build 275-370 GHz Test Plates | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.3.8.11 | Build 89-116 GHz Test Plates | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.3.8.12 | Build 163-211 GHz Test Plates | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.3.8.13 | Build 385-500 GHz Test Plates | 0 | 0 | 6 | 6 | 67 | 260 | 14% | 373 | 422 |
| 4.3.8.14 | Build 125-163 GHz Test Plates | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.3.9.1 | Obtain and evaluate InP IF amplifier wafers | 0 | 0 | 0 | 0 | 0 | 0 | 10% | 0 | 0 |
| 4.3.9.2 | Build IF amplifiers | 0 | 0 | 6 | 32 | 168 | 104 | 10% | 300 | 339 |
| 4.4.1 | Contract for HFET wafer | 0 | 0 | 0 | 0 | 0 | 0 | 24% | 0 | 0 |
| 4.4.2 | Receive and evaluate InP LNA wafer | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.4.3.1 | Build 31-45 GHz HFET Detector Modules | 0 | 0 | 0 | 0 | 0 | 0 | 10% | 0 | 0 |
| 4.4.4.1 | Design 67-90 GHz amplifier | 0 | 0 | 0 | 0 | 0 | 0 | 26% | 0 | 0 |
| 4.4.4.2 | Build 67-90 GHz HFET Detector Modules | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| | | | | | | | | | | |
| 5.1 | LO Reference: Prototype Systems | 0 | 0 | 0 | 1 | 4 | 0 | 20% | 5 | 5 |
| 5.2.1 | Production test and lab equipment | 0 | 0 | 0 | 0 | 0 | 0 | 10% | 0 | 0 |
| 5.2.2 | H-maser Frequency Standard (& Rb) | 0 | 0 | 0 | 0 | 0 | 0 | 8% | 0 | 0 |
| 5.2.3 | 8 GHz PL Oscillator & Distributor | 0 | 0 | 2 | 3 | 26 | 36 | 12% | 69 | 78 |
| 5.2.4 | 10 GHz PL Oscillator & Distributor | 0 | 0 | 2 | 3 | 26 | 36 | 12% | 69 | 78 |
| 5.2.5 | 12 GHz PL Oscillator & Distributor | 0 | 0 | 2 | 3 | 26 | 36 | 12% | 69 | 78 |
| 5.2.6 | 14 GHz PL Oscillator & Distributor | 0 | 0 | 2 | 3 | 26 | 36 | 12% | 69 | 78 |
| 5.2.7 | 3.2-5.2 GHz Synthesizer | 0 | 0 | 2 | 13 | 65 | 336 | 16% | 465 | 527 |
| 5.2.8 | 3.2 -5.2 GHz PLO and Fringe Generator | 0 | 0 | 2 | 7 | 42 | 118 | 14% | 182 | 206 |
| 5.2.9 | Sampler Clock 4 GHz PL Osc & Distributor | 0 | 0 | 2 | 4 | 30 | 36 | 12% | 74 | 83 |
| 5.2.10 | LO Ref Generator | 0 | 0 | 1 | 1 | 11 | 0 | 12% | 12 | 14 |
| 5.2.11 | LO Ref Distributor - Control Bldg | 0 | 0 | 1 | 1 | 11 | 0 | 14% | 13 | 14 |
| 5.2.12 | Microwave Round-trip Phase Measurement | 0 | 0 | 3 | 6 | 45 | 108 | 49% | 229 | 259 |
| 5.2.13 | 10-15 GHz Frequency Synthesizer | 0 | 0 | 2 | 7 | 42 | 71 | 49% | 168 | 190 |
| 5.2.14 | First LO Fringe Generator | 0 | 0 | 1 | 7 | 35 | 118 | 16% | 177 | 200 |
| 5.2.15 | 16 GHz PL Oscillator & Distributor | 0 | 0 | 1 | 3 | 19 | 36 | 12% | 61 | 69 |
| 5.2.16 | 26 GHz PL Oscillator & Distributor | 0 | 0 | 1 | 3 | 19 | 36 | 12% | 61 | 69 |
| 5.2.17 | LO Ref Distributor - Antenna | 0 | 0 | 1 | 3 | 19 | 48 | 18% | 79 | 89 |
| 5.2.18 | VXCO Clean-up Loop | 0 | 0 | 1 | 3 | 19 | 106 | 100% | 251 | 284 |
| 5.2.19 | Power supply module | 0 | 0 | 1 | 2 | 15 | 19 | 5% | 36 | 40 |
| 5.2.20 | Bins / Racks (assemble and test) | 0 | 0 | 0 | 1 | 4 | 11 | 14% | 17 | 19 |
| 5.3.1 | LO Source Design and System Integration | 0 | 0 | 12 | 18 | 157 | 20 | 36% | 241 | 273 |
| 5.3.2.1 | 72-95 GHz LO Source Procurement & Fabrication | 0 | 0 | 0 | 0 | 0 | 0 | 24% | 0 | 0 |
| 5.3.2.2 | 72-95 GHz LO Source Assembly & Test | 0 | 0 | 0 | 0 | 0 | 0 | 24% | 0 | 0 |
| 5.3.3.1 | 102-120 GHz LO Source Procurement & Fabrication | 0 | 0 | 0 | 0 | 0 | 0 | 24% | 0 | 0 |
| 5.3.3.2 | 102-120 GHz LO Source Assembly & Test | 0 | 0 | 0 | 0 | 0 | 0 | 24% | 0 | 0 |
| 5.3.4.1 | 87-108 GHz LO Source Procurement & Fabrication | 0 | 0 | 2 | 12 | 61 | 229 | 24% | 360 | 408 |
| 5.3.4.2 | 87-108 GHz LO Source Assembly & Test | 0 | 0 | 2 | 2 | 22 | 5 | 24% | 34 | 38 |
| 5.3.5.1 | 65-86 GHz LO Source Procurement & Fabrication | 0 | 0 | 2 | 12 | 61 | 229 | 24% | 360 | 408 |
| 5.3.5.2 | 65-86 GHz LO Source Assembly & Test | 0 | 0 | 2 | 2 | 22 | 5 | 24% | 34 | 38 |
| 5.4.1 | LO Multiplier Chain Design & System Integration | 0 | 0 | 18 | 18 | 201 | 335 | 36% | 729 | 825 |
| 5.4.2.1 | 211-275 GHz Receiver LO multiplier Parts | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.2.2 | 211-275 GHz Receiver LO Multiplier Assembly & Test | 0 | 0 | 1 | 2 | 11 | 0 | 34% | 15 | 17 |
| 5.4.2.3 | 275-370 GHz LO integrate source & multiplier | 0 | 0 | 3 | 8 | 53 | 9 | 34% | 83 | 94 |
| 5.4.3.1 | 602-720 GHz Receiver LO multiplier Parts | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.3.2 | 602-720 GHz Receiver LO multiplier Assembly & Test | 0 | 0 | 1 | 8 | 38 | 0 | 34% | 52 | 58 |

# Millimeter Array Construction: 2004

US Reference Project

| WBS | Task Name | Scientists Work-months | Programmers Work-months | Engineers Work-months | Technicians Work-months | Personnel 1999 $K | Materials & Supplies 1999 $K | Contingency | Total Cost 1999 $K | Inflated Cost 2004 $K |
|---|---|---|---|---|---|---|---|---|---|---|
| 5.4.3.3 | 602-720 GHz LO integrate source & multiplier | 0 | 0 | 4 | 12 | 76 | 18 | 34% | 126 | 142 |
| 5.4.4.1 | 275-370 GHz Receiver LO multiplier Parts | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.4.2 | 275-370 GHz Receiver LO multiplier Assembly & Test | 0 | 0 | 1 | 12 | 54 | 0 | 34% | 72 | 82 |
| 5.4.4.3 | 275-370 GHz LO integrate source & multiplier | 0 | 0 | 4 | 12 | 76 | 18 | 34% | 126 | 142 |
| 5.4.5.1 | 163-211 GHz Receiver LO multiplier Parts | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.5.2 | 163-211 GHz Receiver LO multiplier Assembly & Test | 0 | 0 | 1 | 5 | 27 | 0 | 34% | 36 | 41 |
| 5.4.5.3 | 163-211 GHz LO integrate source & multiplier | 0 | 0 | 3 | 8 | 53 | 9 | 34% | 83 | 94 |
| 5.4.6.1 | 385-500 GHz Receiver LO multiplier Parts | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.6.2 | 385-500 GHz Receiver LO multiplier Assembly & Test | 0 | 0 | 1 | 5 | 27 | 0 | 34% | 36 | 41 |
| 5.4.6.3 | 385-500 GHz LO integrate source & multiplier | 0 | 0 | 4 | 12 | 76 | 20 | 34% | 128 | 145 |
| 5.4.7.1 | 125-163 GHz Receiver LO multiplier Parts | 0 | 0 | 1 | 2 | 11 | 6 | 34% | 24 | 27 |
| 5.4.7.2 | 125-163 GHz Receiver LO multiplier Assembly & Test | 0 | 0 | 1 | 2 | 11 | 0 | 34% | 15 | 17 |
| 5.4.7.3 | 125-163 GHz LO integrate source & multiplier | 0 | 0 | 1 | 2 | 15 | 0 | 34% | 20 | 23 |
| 5.4.8.1 | Design & fab 31-45 GHz receiver LO coupling | 0 | 0 | 0 | 0 | 0 | 0 | 12% | 0 | 0 |
| 5.4.9 | LO Multiplier Fabrication Equipment | 0 | 0 | 0 | 0 | 0 | 0 | 11% | 0 | 0 |
| 5.4.10 | LO Multiplier Test Equipment | 0 | 0 | 0 | 0 | 0 | 0 | 11% | 0 | 0 |
| | | | | | | | | | | |
| 6.1 | IF Field Prototype for Test Interferometer of 2 antennas. | 0 | 0 | 0 | 0 | 0 | 0 | 10% | 0 | 0 |
| 6.2 | IF Construction test & lab equipment | 0 | 0 | 0 | 0 | 0 | 0 | 5% | 0 | 0 |
| 6.3 | IF Multiplexer (2/antenna) | 0 | 0 | 7 | 13 | 102 | 506 | 20% | 729 | 824 |
| 6.4 | IF Demultiplexer (2/antenna) | 0 | 0 | 5 | 13 | 87 | 179 | 10% | 292 | 331 |
| 6.5 | IF Matrix Switch (2/antenna) | 0 | 0 | 1 | 5 | 27 | 111 | 6% | 146 | 165 |
| 6.6 | IF Baseband Converter (8/antenna) | 0 | 0 | 6 | 13 | 94 | 430 | 20% | 629 | 712 |
| 6.7 | IF Power Supply module | 0 | 0 | 0 | 1 | 4 | 14 | 5% | 19 | 22 |
| 6.8 | Bins / Racks (assemble and test) | 0 | 0 | 1 | 3 | 19 | 33 | 5% | 54 | 62 |
| | | | | | | | | | | |
| 7.1 | Prototype Optical Fiber Systems | 0 | 0 | 0 | 0 | 0 | 0 | 32% | 0 | 0 |
| 7.2 | Digital IF Transmitters and Receivers | 0 | 0 | 18 | 27 | 236 | 714 | 40% | 1,329 | 1,504 |
| 7.3.1 | 16 GHZ FO LO Ref Dist Prototype | 0 | 0 | 0 | 0 | 0 | 0 | 40% | 0 | 0 |
| 7.3.2 | 16 GHz FO LO Ref Dist with Integrated R/T Phase Meas. | 0 | 0 | 24 | 36 | 315 | 139 | 28% | 580 | 656 |
| 7.4 | Production Test Equipment | 0 | 0 | 0 | 0 | 0 | 0 | 5% | 0 | 0 |
| 7.5 | Monitor and Control Transmitters and Receivers | 0 | 0 | 5 | 12 | 83 | 44 | 14% | 145 | 164 |
| 7.6 | Fiber Optics Power Supply Modules | 0 | 0 | 2 | 4 | 30 | 15 | 14% | 52 | 59 |
| 7.7 | Bins / Racks (assemble and test) | 0 | 0 | 4 | 8 | 60 | 20 | 14% | 91 | 103 |
| | | | | | | | | | | |
| 8.1.1 | Refine digitizer design | 0 | 0 | 0 | 0 | 0 | 0 | 30% | 0 | 0 |
| 8.1.3 | Digitizer contract materials | 0 | 0 | 0 | 0 | 0 | 0 | 30% | 0 | 0 |
| 8.1.4 | Assembly of digitizers | 0 | 0 | 0 | 0 | 0 | 0 | 26% | 0 | 0 |
| 8.1.5 | Digitizer validation and delivery | 0 | 0 | 0 | 0 | 0 | 0 | 26% | 0 | 0 |
| 8.2.1 | Prototype FIR filter testing on interferometer | 0 | 0 | 0 | 0 | 0 | 0 | 38% | 0 | 0 |
| 8.2.2 | Design & test FIR filter refinement | 0 | 0 | 0 | 0 | 0 | 0 | 32% | 0 | 0 |
| 8.2.4 | FIR filter chip & board fabrication | 0 | 0 | 0 | 0 | 0 | 0 | 32% | 0 | 0 |
| 8.2.5 | FIR filter board assembly | 0 | 0 | 0 | 0 | 0 | 0 | 26% | 0 | 0 |
| 8.2.6 | FIR filter board validation and delivery | 0 | 0 | 0 | 0 | 0 | 0 | 32% | 0 | 0 |
| 8.3.1 | Correlator boards | 0 | 0 | 0 | 0 | 0 | 0 | 26% | 0 | 0 |
| 8.4 | Correlator Chip | 0 | 0 | 0 | 0 | 0 | 0 | 30% | 0 | 0 |
| 8.6 | Correlator software | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 8.5 | Correlator Racks | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 8.7 | Prototype Correlator Production | 0 | 0 | 0 | 0 | 0 | 0 | 28% | 0 | 0 |
| 8.8.1 | First 1/4 Correlator | 0 | 0 | 18 | 18 | 201 | 10 | 28% | 270 | 305 |
| 8.8.2 | Second 1/4 Correlator | 0 | 0 | 18 | 18 | 201 | 0 | 24% | 249 | 282 |
| 8.8.3 | Third 1/4 Correlator | 0 | 0 | 0 | 0 | 0 | 389 | 24% | 482 | 546 |

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| WBS | Task Name | Scientists Work-months | Programmers Work-months | Engineers Work-months | Technicians Work-months | Personnel 1999 $K | Materials & Supplies 1999 $K | Contingency | Total Cost 1999 $K | Inflated Cost 2004 $K |
|---|---|---|---|---|---|---|---|---|---|---|
| 8.8.4 | Fourth 1/4 Correlator | 0 | 0 | 0 | 0 | 0 | 0 | 24% | 0 | 0 |
| 8.9 | Correlator test equipment | 0 | 0 | 0 | 0 | 0 | 0 | 5% | 0 | 0 |
| | | | | | | | | | | |
| 9 | Computing | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.1 | Control Software | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.1.1 | Test Interferometer Control and Analysis | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 9.1.2 | MMA Correlator Software | 0 | 36 | 0 | 0 | 215 | 0 | 34% | 287 | 325 |
| 9.1.3 | Multi-antenna & sub-array control | 0 | 24 | 0 | 0 | 143 | 140 | 34% | 379 | 429 |
| 9.1.4 | Operators and Observers Interfaces | 0 | 18 | 0 | 0 | 107 | 5 | 34% | 150 | 170 |
| 9.1.5 | Deliver control software | 0 | 0 | 0 | 0 | 0 | 0 | 30% | 0 | 0 |
| 9.1.6 | Maintenance | 0 | 0 | 0 | 0 | 0 | 0 | 18% | 0 | 0 |
| 9.2 | Scheduling | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.2.1 | Static Scheduling System | 0 | 9 | 0 | 0 | 54 | 0 | 34% | 72 | 81 |
| 9.2.2 | Dynamic scheduling simulations | 12 | 0 | 0 | 0 | 86 | 0 | 34% | 115 | 130 |
| 9.2.3 | Dynamic scheduling prototype | 0 | 0 | 0 | 0 | 0 | 0 | 30% | 0 | 0 |
| 9.2.4 | Dynamic scheduling implementation | 0 | 0 | 0 | 0 | 0 | 0 | 39% | 0 | 0 |
| 9.3 | Proposal preparation software | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.3.1 | Proposal assistance prototype | 3 | 6 | 0 | 0 | 57 | 0 | 30% | 74 | 84 |
| 9.3.2 | Proposal assistance implementation | 0 | 0 | 0 | 0 | 0 | 0 | 30% | 0 | 0 |
| 9.3.3 | Observe program prototype | 3 | 6 | 0 | 0 | 57 | 0 | 26% | 72 | 82 |
| 9.3.4 | Observe program | 0 | 0 | 0 | 0 | 0 | 0 | 26% | 0 | 0 |
| 9.4 | Image pipeline | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.4.1 | Automated calibration & imaging heuristics | 6 | 0 | 0 | 0 | 43 | 0 | 39% | 60 | 67 |
| 9.4.2 | Prototype image pipeline | 3 | 6 | 0 | 0 | 57 | 0 | 30% | 74 | 84 |
| 9.4.3 | Parallelization studies and implementation | 0 | 12 | 0 | 0 | 72 | 55 | 34% | 170 | 192 |
| 9.4.4 | Initial image pipeline operations | 0 | 0 | 0 | 0 | 0 | 0 | 26% | 0 | 0 |
| 9.4.5 | Production image pipeline | 0 | 0 | 0 | 0 | 0 | 0 | 30% | 0 | 0 |
| 9.5 | Archiving | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.5.1 | Prototype distributed archive | 3 | 6 | 0 | 0 | 57 | 0 | 30% | 74 | 84 |
| 9.5.2 | Evaluate storage hardware | 0 | 0 | 0 | 0 | 0 | 0 | 11% | 0 | 0 |
| 9.5.3 | Production archive | 0 | 0 | 0 | 0 | 0 | 0 | 30% | 0 | 0 |
| 9.6 | Post processing | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.6.1 | Define data formats | 0 | 0 | 0 | 0 | 0 | 0 | 18% | 0 | 0 |
| 9.6.2 | Filler and format conversions | 0 | 6 | 0 | 0 | 36 | 0 | 22% | 44 | 49 |
| 9.6.3 | ALMA specific calibrations | 6 | 0 | 0 | 0 | 43 | 0 | 39% | 60 | 67 |
| 9.6.4 | MMA Post-processing begins | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.6.5 | Maintenance | 0 | 0 | 0 | 0 | 0 | 0 | 22% | 0 | 0 |
| 9.7 | Software support | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.7.1 | Tool support | 0 | 6 | 0 | 0 | 36 | 0 | 34% | 48 | 54 |
| 9.7.2 | Quality assurance | 0 | 12 | 0 | 0 | 72 | 0 | 34% | 96 | 108 |
| 9.7.3 | Chile system administration | 0 | 0 | 0 | 0 | 0 | 0 | 22% | 0 | 0 |
| | | | | | | | | | | |
| 10 | System Integration | 0 | 0 | 0 | 0 | 0 | 0 | 10% | 0 | 0 |
| 10.4 | Test Interferometer Site Preparation | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.10 | Oufitting at U.S. test site | 0 | 0 | 0 | 0 | 0 | 0 | 12% | 0 | 0 |
| 10.10.4 | Antenna #1 Outfitting | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.10.7 | Antenna #2 Outfitting | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.10.10 | General Outfitting | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.11 | Single Dish Tests | 0 | 0 | 0 | 0 | 0 | 0 | 11% | 0 | 0 |
| 10.11.1 | Ant #1 holography and surface readjustment | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.11.2 | Ant #1 Antenna Evaluation | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.11.6 | Ant #2 holography and surface readjustment | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |

# Millimeter Array Construction: 2004

US Reference Project

| WBS | Task Name | Scientists Work-months | Programmers Work-months | Engineers Work-months | Technicians Work-months | Personnel 1999 $K | Materials & Supplies 1999 $K | Contingency | Total Cost 1999 $K | Inflated Cost 2004 $K |
|---|---|---|---|---|---|---|---|---|---|---|
| 10.11.7 | Ant #2 Antenna Evaluation | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.12 | Interferometric Tests | 0 | 0 | 0 | 0 | 0 | 0 | 11% | 0 | 0 |
| 10.12.1 | Phase/gain stability tests | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.12.2 | Sensitivity verification | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.12.3 | Holography with astronomical sources | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.12.4 | Modifications and Retrofits | 6 | 3 | 6 | 3 | 116 | 0 | 35% | 157 | 177 |
| 10.13 | Dissassemble test system and ship to array site | 0 | 0 | 0 | 0 | 0 | 0 | 35% | 0 | 0 |
| 10.14 | On-site System Integration | 0 | 0 | 0 | 0 | 0 | 0 | 50% | 0 | 0 |
| 10.14.1 | Set up assembly and test facilities at OSF | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.14.2 | Outfit antennas 3 through 36 | 0 | 0 | 0 | 0 | 0 | 10 | 25% | 13 | 14 |
| 10.14.2.1 | Wiring and plumbing | 0 | 0 | 0 | 7 | 25 | 77 | 25% | 128 | 145 |
| 10.14.2.2 | Install electronics in receiver cabin | 0 | 0 | 0 | 7 | 25 | 77 | 25% | 128 | 145 |
| 10.14.2.3 | Check out completed antenna at OSF | 2 | 0 | 7 | 7 | 84 | 0 | 25% | 105 | 119 |
| 10.14.2.4 | Install antenna at array site. | 0 | 0 | 0 | 7 | 28 | 0 | 25% | 36 | 40 |
| 10.14.3 | Refurbish antennas 1 and 2 | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.14.3.1 | Re-install electronics and upgrade as needed | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.14.3.2 | Check out at OSF | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.14.3.3 | Install antenna at array site | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.14.4 | Install central building electronics | 0 | 0 | 2 | 1 | 16 | 0 | 25% | 21 | 23 |
| 10.14.5 | Support debugging and repair | 0 | 0 | 6 | 12 | 90 | 0 | 25% | 113 | 128 |
| 10.20 | Prototype Testing Support | 0 | 0 | 1 | 1 | 11 | 10 | 10% | 23 | 26 |
| | | | | | | | | | | |
| 11.1.1 | Completion of 183 GHz Water Vapor Radiometer | 0 | 0 | 0 | 0 | 0 | 0 | 11% | 0 | 0 |
| 11.1.2 | Demonstrate 183 GHz Water Vapor Radiometer | 0 | 0 | 0 | 0 | 0 | 0 | 12% | 0 | 0 |
| 11.1.3 | Refinement of 183 GHz Water Vapor Radiometer | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 11.1.4 | Release WVR for manufacture | 0 | 0 | 0 | 0 | 0 | 0 | 10% | 0 | 0 |
| 11.2.1.1 | Contract Phase Monitor Radiometer Subassembly | 0 | 0 | 0 | 0 | 0 | 0 | 10% | 0 | 0 |
| 11.2.1.2 | WVR Spectrometer | 0 | 0 | 0 | 0 | 0 | 75 | 10% | 83 | 93 |
| 11.2.1.3 | WVR Feed, Window, Lens, Instrumentation | 0 | 0 | 0 | 0 | 0 | 0 | 10% | 0 | 0 |
| 11.2.1.4 | Monitor and Control WVR Interface | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 11.2.3 | Deliver Production Radiometers | 0 | 0 | 0 | 6 | 23 | 3 | 9% | 28 | 32 |
| 11.2.4 | Integration of WVR into Receiver Package | 0 | 0 | 0 | 12 | 47 | 0 | 7% | 50 | 57 |
| 11.2.5 | Verification on Site of WVR | 0 | 3 | 0 | 3 | 30 | 0 | 9% | 32 | 36 |
| 11.3.1 | Dual-Load Amp. Calibration Device Design Refinement | 0 | 0 | 0 | 0 | 0 | 0 | 7% | 0 | 0 |
| 11.3.2 | Release Dual-Load Amp Cal for Mftr | 0 | 0 | 0 | 0 | 0 | 0 | 8% | 0 | 0 |
| 11.3.3 | Contract Subassembly Dual-Load Amp Cal | 0 | 0 | 0 | 0 | 0 | 0 | 7% | 0 | 0 |
| 11.3.3.1 | Dual-Load AmpCal Subassy Machining | 0 | 0 | 0 | 0 | 0 | 0 | 7% | 0 | 0 |
| 11.3.3.2 | Load Fabrication for Dual Load Amp Cal | 0 | 0 | 0 | 0 | 0 | 0 | 7% | 0 | 0 |
| 11.3.3.3 | Dual Load Amplitude Calibration Device Motors, Servo | 0 | 0 | 0 | 0 | 0 | 0 | 7% | 0 | 0 |
| 11.3.3.4 | M/C Interface for Dual Load Amp Cal Device | 0 | 0 | 0 | 0 | 0 | 0 | 7% | 0 | 0 |
| 11.3.4 | Assembly and Test of Dual Load Amplitude Calibration | 0 | 0 | 0 | 0 | 0 | 0 | 7% | 0 | 0 |
| 11.3.5 | Integration of AmpCal on Production Antennas | 0 | 0 | 0 | 3 | 12 | 0 | 7% | 13 | 14 |
| 11.4 | Imaging Studies and Project Support | 0 | 0 | 0 | 0 | 0 | 0 | 5% | 0 | 0 |
| 11.5 | Imaging Algorithm Development | 12 | 0 | 0 | 0 | 86 | 0 | 7% | 92 | 104 |
| | | | | | | | | | | |
| | Totals | 116 | 153 | 448 | 954 | 8,712 | 22,994 | | 39,756 | 44,901 |

# Millimeter Array Construction: 2005

US Reference Project

| WBS | Task Name | Scientists Work-months | Programmers Work-months | Engineers Work-months | Technicians Work-months | Personnel 1999 $K | Materials & Supplies 1999 $K | Contingency | Total Cost 1999 $K | Inflated Cost 2005 $K |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.1 | Project Management | 60 | 0 | 0 | 24 | 523 | 0 | 15% | 601 | 697 |
| 1.1.1 | Management, Planning, and Oversight | 0 | 0 | 0 | 0 | 0 | 705 | 15% | 811 | 940 |
| 1.1.2 | Business Operations | 0 | 0 | 0 | 0 | 0 | 100 | 15% | 115 | 133 |
| 1.1.3 | Chilean Operations | 0 | 0 | 0 | 0 | 0 | 15 | 15% | 17 | 20 |
| 1.1.4 | Safety and Health | 0 | 0 | 0 | 0 | 0 | 0 | 15% | 0 | 0 |
| 1.1.5 | Personnel | 0 | 0 | 0 | 0 | 0 | 0 | 15% | 0 | 0 |
| 1.1.6 | Project Science Office | 0 | 0 | 0 | 0 | 0 | 0 | 15% | 0 | 0 |
| 1.1.7 | AUI Management | 0 | 0 | 0 | 0 | 0 | 350 | 15% | 402 | 467 |
| 1.2 | Engineering | 0 | 0 | 24 | 12 | 221 | 20 | 15% | 277 | 321 |
| 1.2.1 | System Engineering--Phase II | 0 | 0 | 0 | 0 | 0 | 0 | 15% | 0 | 0 |
| 1.2.2 | Documentation System | 0 | 0 | 0 | 0 | 0 | 0 | 15% | 0 | 0 |
| 1.2.3 | Production Engineering | 0 | 0 | 0 | 0 | 0 | 0 | 15% | 0 | 0 |
| 1.3 | US Facilities | 0 | 0 | 0 | 0 | 0 | 0 | 15% | 0 | 0 |
| 1.3.1 | CDL Permanent Facilities | 0 | 0 | 0 | 0 | 0 | 600 | 0% | 600 | 600 |
| 1.3.2 | Manufacturing Facilities | 0 | 0 | 0 | 0 | 0 | 115 | 10% | 127 | 147 |
| 1.3.3 | Common Infrastructure | 0 | 0 | 0 | 0 | 0 | 200 | 15% | 230 | 267 |
| | | | | | | | | | | |
| 2 | Site Development | 0 | 0 | 12 | 0 | 87 | 50 | 5% | 144 | 167 |
| 2.2 | Maintain Mining claims | 0 | 0 | 0 | 0 | 0 | 25 | 5% | 26 | 30 |
| 2.3 | Contract A&E Studies | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 2.5.3 | Contract Array Site Civil Works | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 2.6.3 | Contract OSF Civil Works | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 2.7.3 | Contract Civil Works | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 2.8.1 | Equip Array Site | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 2.8.2 | Equip Operations Support Facility | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| | | | | | | | | | | |
| 3.1 | Antenna Engineering Support | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 3.8.10 | Sign Transporter Contract | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 3.8.30 | Accept Transporter #2 at OSF | 0 | 0 | 0 | 0 | 0 | 740 | 20% | 888 | 1,030 |
| 3.8.35 | Contract for Transporter #1 Move to site | 0 | 0 | 0 | 0 | 0 | 20 | 12% | 22 | 26 |
| 3.15 | Procurement of Antenna 2 | 0 | 0 | 0 | 0 | 0 | 0 | 27% | 0 | 0 |
| 3.20 | Sign Contract for Production Antennas | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 3.21 | Antenna Contract Supervision | 0 | 0 | 36 | 0 | 261 | 0 | 12% | 293 | 339 |
| 3.23 | Accept Antenna #3 at OSF | 0 | 0 | 0 | 0 | 0 | 0 | 27% | 0 | 0 |
| 3.25, 3.27, 3.2 | Accept Antennas #4 through #36 | 0 | 0 | 14 | 0 | 98 | 24,786 | 27% | 31,603 | 36,649 |
| | | | | | | | | | | |
| 4.1.1.2 | Fabricate PPRC | 0 | 0 | 0 | 0 | 0 | 0 | 28% | 0 | 0 |
| 4.1.1.3 | Test PPRC | 0 | 0 | 0 | 0 | 0 | 0 | 5% | 0 | 0 |
| 4.1.2.1 | PPR Dewar Design | 0 | 0 | 0 | 0 | 0 | 0 | 17% | 0 | 0 |
| 4.1.2.2 | PPR Dewar Fabrication and Vacuum Testing | 0 | 0 | 0 | 0 | 0 | 0 | 40% | 0 | 0 |
| 4.1.2.3 | PPR Vacuum Windows and IR Filters | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 4.1.2.4 | PPR Cryogenics/Dewar Assembly and Testing | 0 | 0 | 0 | 0 | 0 | 0 | 13% | 0 | 0 |
| 4.1.3.1 | PPR Control-Monitoring and Bias Electronics Design | 0 | 0 | 0 | 0 | 0 | 0 | 21% | 0 | 0 |
| 4.1.3.2 | PPR Control-Monitor and Bias Electronics Construction | 0 | 0 | 0 | 0 | 0 | 0 | 44% | 0 | 0 |
| 4.1.4.1 | Insert Mechanical-Thermal Design, Bands <275 GHz (Waveguide | 0 | 0 | 0 | 0 | 0 | 0 | 48% | 0 | 0 |
| 4.1.4.2 | Insert Component Fabrication for Bands <275 GHz | 0 | 0 | 0 | 0 | 0 | 0 | 56% | 0 | 0 |
| 4.1.4.3 | Insert Mechanical-Thermal Design for Bands >275 GHz (Quasi o | 0 | 0 | 0 | 0 | 0 | 0 | 48% | 0 | 0 |
| 4.1.4.4 | Insert Component Fabrication for Bands >275 Ghz | 0 | 0 | 0 | 0 | 0 | 0 | 56% | 0 | 0 |
| 4.1.4.8 | PPR Insert Assembly (3 Bands) | 0 | 0 | 0 | 0 | 0 | 0 | 44% | 0 | 0 |
| 4.1.4.9 | PPR Insert Testing (3 Bands) | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.1.5.1 | PPR Vacuum System Assembly | 0 | 0 | 0 | 0 | 0 | 0 | 8% | 0 | 0 |
| 4.1.7.1 | PPR Post IF System Design | 0 | 0 | 0 | 0 | 0 | 0 | 22% | 0 | 0 |

# Millimeter Array Construction: 2005

US Reference Project

| WBS | Task Name | Scientists Work-months | Programmers Work-months | Engineers Work-months | Technicians Work-months | Personnel 1999 $K | Materials & Supplies 1999 $K | Contingency | Total Cost 1999 $K | Inflated Cost 2005 $K |
|---|---|---|---|---|---|---|---|---|---|---|
| 4.1.7.2 | PPR Post IF System Construction and Testing | 0 | 0 | 0 | 0 | 0 | 0 | 24% | 0 | 0 |
| 4.1.8.1 | PPR Frame Design | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.1.8.2 | PPR Frame Fabrication | 0 | 0 | 0 | 0 | 0 | 0 | 30% | 0 | 0 |
| 4.1.9.1 | Prototype Production Receiver Integration | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.1.9.2 | PPR Testing and Evaluation | 0 | 0 | 0 | 0 | 0 | 0 | 36% | 0 | 0 |
| 4.1.10.1 | Design and build Prototype and Production Receiver Test Set | 0 | 0 | 0 | 0 | 0 | 0 | 36% | 0 | 0 |
| 4.1.10.2 | Design and Fabricate Receiver Insert Test Set | 0 | 0 | 0 | 0 | 0 | 0 | 11% | 0 | 0 |
| 4.1.10.3 | General Test Equipment | 0 | 0 | 0 | 0 | 0 | 0 | 13% | 0 | 0 |
| 4.2.1 | MMA Receiver (MMA Rx) Design Refinement | 0 | 0 | 0 | 0 | 0 | 0 | 28% | 0 | 0 |
| 4.2.2 | MMA Receiver (MMA Rx) Documentation | 0 | 0 | 0 | 0 | 0 | 0 | 18% | 0 | 0 |
| 4.2.4.1 | MMA Rx Dewar Fabrication | 0 | 0 | 1 | 10 | 46 | 70 | 16% | 135 | 156 |
| 4.2.4.2 | MMA Rx Cryogenics Fabrication | 0 | 0 | 3 | 30 | 139 | 660 | 20% | 959 | 1,112 |
| 4.2.4.3 | Vacuum Windows and IR Filters Fabrication | 0 | 0 | 2 | 11 | 57 | 82 | 16% | 162 | 187 |
| 4.2.4.4 | Receiver Insert Fabrication | 0 | 0 | 2 | 80 | 327 | 693 | 22% | 1,244 | 1,442 |
| 4.2.4.5 | MMA Receiver Frame Fabrication and assembly | 0 | 0 | 1 | 20 | 85 | 150 | 16% | 273 | 316 |
| 4.2.4.6 | Vacuum System Fabrication and testing. | 0 | 0 | 0 | 5 | 20 | 200 | 16% | 255 | 295 |
| 4.2.4.7 | Bias and Control-Monitoring Electronics Construction | 0 | 0 | 1 | 4 | 23 | 240 | 16% | 305 | 354 |
| 4.2.4.9 | Assemble Receiver Inserts and Test | 0 | 0 | 40 | 80 | 602 | 667 | 20% | 1,523 | 1,766 |
| 4.2.4.10 | Assemble MMA Rx IF System | 0 | 0 | 1 | 5 | 27 | 145 | 14% | 196 | 227 |
| 4.2.6.1 | Integrate Test & Commission MMA Receivers | 0 | 0 | 15 | 30 | 226 | 30 | 16% | 297 | 344 |
| 4.5.1 | Construct and test Cryo system for 2nd Evaluation Receiver | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.5.2 | Fabrication and assembly of 2nd Evaluation Receiver. | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.5.3 | Test and Commission 2nd Evaluation Receiver | 0 | 0 | 0 | 0 | 0 | 0 | 5% | 0 | 0 |
| 4.3.1.1 | Design, Fab, and Test 211-275 GHz Mixer Design | 0 | 0 | 0 | 0 | 0 | 0 | 52% | 0 | 0 |
| 4.3.1.3 | Fabricate 211-275 GHz mixer blocks | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.3.1.4 | Fabricate & test 211-275 GHz SIS Mixer Detector Modules | 0 | 0 | 0 | 0 | 0 | 0 | 52% | 0 | 0 |
| 4.3.2.1 | Design, Fab, and Test 602-720 GHz Mixer Design | 0 | 0 | 0 | 0 | 0 | 0 | 52% | 0 | 0 |
| 4.3.2.3 | Fabricate 602-720 GHz mixer blocks | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.3.2.4 | Fabricate & test 602-720 GHz SIS Mixer Detector Modules | 0 | 0 | 0 | 0 | 0 | 0 | 78% | 0 | 0 |
| 4.3.3.1 | Design, Fab, and Test 275-370 GHz Mixer Design | 0 | 0 | 0 | 0 | 0 | 0 | 52% | 0 | 0 |
| 4.3.3.3 | Fabricate 275-370 GHz mixer blocks | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.3.3.4 | Fabricate & test 275-370 GHz SIS Mixer Detector Modules | 0 | 0 | 0 | 0 | 0 | 0 | 52% | 0 | 0 |
| 4.3.4.1 | Design, Fab, and Test 89-116 GHz Mixer Design | 0 | 0 | 0 | 0 | 0 | 0 | 52% | 0 | 0 |
| 4.3.4.3 | Fabricate 89-116 GHz mixer blocks | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.3.4.4 | Fabricate 89-116 GHz SIS Mixer Detector Modules | 0 | 0 | 0 | 0 | 0 | 0 | 52% | 0 | 0 |
| 4.3.5.1 | Design, Fab, and Test 163-211 GHz Mixer Design | 0 | 0 | 0 | 0 | 0 | 0 | 52% | 0 | 0 |
| 4.3.5.3 | Fabricate 163-211 GHz Mixer Blocks | 0 | 0 | 0 | 5 | 20 | 3 | 16% | 26 | 30 |
| 4.3.5.4 | Fabricate & test 163-211 GHz SIS Mixer Detector Modules | 0 | 0 | 10 | 24 | 166 | 265 | 52% | 656 | 761 |
| 4.3.6.1 | Design, Fab, and Test 385-500 GHz Mixer Design | 0 | 0 | 0 | 0 | 0 | 0 | 52% | 0 | 0 |
| 4.3.6.3 | Fabricate 385-500 GHz mixer blocks | 0 | 0 | 0 | 7 | 27 | 9 | 16% | 42 | 49 |
| 4.3.6.4 | Fabricate & Test 385-500 GHz SIS Mixer Detector Modules | 0 | 0 | 12 | 30 | 204 | 354 | 52% | 848 | 984 |
| 4.3.7.1 | Design, Fab, and Test 125-163 GHz Mixer Design | 0 | 0 | 32 | 38 | 380 | 332 | 52% | 1,083 | 1,256 |
| 4.3.7.3 | Fabricate 125-163 GHz mixer blocks | 0 | 0 | 0 | 2 | 8 | 1 | 16% | 10 | 12 |
| 4.3.7.4 | Fabricate & Test 125-163 GHz SIS Mixer Detector Modules | 0 | 0 | 2 | 5 | 34 | 110 | 34% | 193 | 224 |
| 4.3.8.1 | Build SIS Fabrication Equipment | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.3.8.2 | Build SIS Test Dewar & Rack #1 | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.3.8.3 | Build SIS Test Dewar & Rack #2 | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.3.8.4 | Build SIS Test Dewar & Rack #3 | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.3.8.5 | Build SIS Test Dewar & Rack #4 | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.3.8.6 | Build Wafer Evaluation Test Sets | 0 | 0 | 0 | 0 | 0 | 0 | 18% | 0 | 0 |
| 4.3.8.7.1 | General SIS Test Equipment | 0 | 0 | 0 | 0 | 0 | 0 | 5% | 0 | 0 |
| 4.3.8.7.2 | Equip Network Analyzer to 330 GHz | 0 | 0 | 0 | 0 | 0 | 0 | 15% | 0 | 0 |

# Millimeter Array Construction: 2005

US Reference Project

| WBS | Task Name | Scientists Work-months | Programmers Work-months | Engineers Work-months | Technicians Work-months | Personnel 1999 $K | Materials & Supplies 1999 $K | Contingency | Total Cost 1999 $K | Inflated Cost 2005 $K |
|---|---|---|---|---|---|---|---|---|---|---|
| 4.3.8.7.3 | Near-Field Antenna Test Equipment | 0 | 0 | 0 | 0 | 0 | 0 | 15% | 0 | 0 |
| 4.3.8.8 | Build 211-275 GHz Test Plates | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.3.8.9 | Build 602-720 GHz Test Plates | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.3.8.10 | Build 275-370 GHz Test Plates | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.3.8.11 | Build 89-116 GHz Test Plates | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.3.8.12 | Build 163-211 GHz Test Plates | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.3.8.13 | Build 385-500 GHz Test Plates | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.3.8.14 | Build 125-163 GHz Test Plates | 0 | 0 | 6 | 6 | 67 | 240 | 14% | 350 | 406 |
| 4.3.9.1 | Obtain and evaluate InP IF amplifier wafers | 0 | 0 | 0 | 0 | 0 | 0 | 10% | 0 | 0 |
| 4.3.9.2 | Build IF amplifiers | 0 | 0 | 6 | 32 | 168 | 104 | 10% | 300 | 347 |
| 4.4.1 | Contract for HFET wafer | 0 | 0 | 0 | 0 | 0 | 0 | 24% | 0 | 0 |
| 4.4.2 | Receive and evaluate InP LNA wafer | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.4.3.1 | Build 31-45 GHz HFET Detector Modules | 0 | 0 | 0 | 0 | 0 | 0 | 10% | 0 | 0 |
| 4.4.4.1 | Design 67-90 GHz amplifier | 0 | 0 | 0 | 0 | 0 | 0 | 26% | 0 | 0 |
| 4.4.4.2 | Build 67-90 GHz HFET Detector Modules | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| | | | | | | | | | | |
| 5.1 | LO Reference: Prototype Systems | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 5.2.1 | Production test and lab equipment | 0 | 0 | 0 | 0 | 0 | 0 | 10% | 0 | 0 |
| 5.2.2 | H-maser Frequency Standard (& Rb) | 0 | 0 | 0 | 0 | 0 | 0 | 8% | 0 | 0 |
| 5.2.3 | 8 GHz PL Oscillator & Distributor | 0 | 0 | 1 | 2 | 15 | 36 | 12% | 57 | 66 |
| 5.2.4 | 10 GHz PL Oscillator & Distributor | 0 | 0 | 1 | 2 | 15 | 36 | 12% | 57 | 66 |
| 5.2.5 | 12 GHz PL Oscillator & Distributor | 0 | 0 | 1 | 2 | 15 | 36 | 12% | 57 | 66 |
| 5.2.6 | 14 GHz PL Oscillator & Distributor | 0 | 0 | 1 | 2 | 15 | 36 | 12% | 57 | 66 |
| 5.2.7 | 3.2-5.2 GHz Synthesizer | 0 | 0 | 1 | 12 | 54 | 336 | 16% | 452 | 525 |
| 5.2.8 | 3.2 -5.2 GHz PLO and Fringe Generator | 0 | 0 | 1 | 6 | 31 | 118 | 14% | 169 | 196 |
| 5.2.9 | Sampler Clock 4 GHz PL Osc & Distributor | 0 | 0 | 1 | 3 | 19 | 36 | 12% | 61 | 71 |
| 5.2.10 | LO Ref Generator | 0 | 0 | 0 | 0 | 0 | 0 | 12% | 0 | 0 |
| 5.2.11 | LO Ref Distributor - Control Bldg | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 5.2.12 | Microwave Round-trip Phase Measurement | 0 | 0 | 3 | 3 | 33 | 108 | 49% | 211 | 245 |
| 5.2.13 | 10-15 GHz Frequency Synthesizer | 0 | 0 | 1 | 6 | 31 | 71 | 49% | 151 | 175 |
| 5.2.14 | First LO Fringe Generator | 0 | 0 | 0 | 6 | 23 | 118 | 16% | 164 | 190 |
| 5.2.15 | 16 GHz PL Oscillator & Distributor | 0 | 0 | 0 | 2 | 8 | 36 | 12% | 49 | 57 |
| 5.2.16 | 26 GHz PL Oscillator & Distributor | 0 | 0 | 0 | 2 | 8 | 36 | 12% | 49 | 57 |
| 5.2.17 | LO Ref Distributor - Antenna | 0 | 0 | 0 | 2 | 8 | 48 | 18% | 65 | 76 |
| 5.2.18 | VXCO Clean-up Loop | 0 | 0 | 0 | 2 | 8 | 106 | 100% | 228 | 265 |
| 5.2.19 | Power supply module | 0 | 0 | 0 | 1 | 4 | 19 | 5% | 24 | 28 |
| 5.2.20 | Bins / Racks (assemble and test) | 0 | 0 | 0 | 0 | 0 | 11 | 14% | 13 | 15 |
| 5.3.1 | LO Source Design and System Integration | 0 | 0 | 12 | 18 | 157 | 20 | 36% | 241 | 280 |
| 5.3.2.1 | 72-95 GHz LO Source Procurement & Fabrication | 0 | 0 | 0 | 0 | 0 | 0 | 24% | 0 | 0 |
| 5.3.2.2 | 72-95 GHz LO Source Assembly & Test | 0 | 0 | 0 | 0 | 0 | 0 | 24% | 0 | 0 |
| 5.3.3.1 | 102-120 GHz LO Source Procurement & Fabrication | 0 | 0 | 0 | 0 | 0 | 0 | 24% | 0 | 0 |
| 5.3.3.2 | 102-120 GHz LO Source Assembly & Test | 0 | 0 | 0 | 0 | 0 | 0 | 24% | 0 | 0 |
| 5.3.4.1 | 87-108 GHz LO Source Procurement & Fabrication | 0 | 0 | 1 | 10 | 46 | 86 | 24% | 164 | 190 |
| 5.3.4.2 | 87-108 GHz LO Source Assembly & Test | 0 | 0 | 1 | 2 | 15 | 2 | 24% | 21 | 24 |
| 5.3.5.1 | 65-86 GHz LO Source Procurement & Fabrication | 0 | 0 | 1 | 10 | 46 | 86 | 24% | 164 | 190 |
| 5.3.5.2 | 65-86 GHz LO Source Assembly & Test | 0 | 0 | 1 | 2 | 15 | 2 | 24% | 21 | 24 |
| 5.4.1 | LO Multiplier Chain Design & System Integration | 0 | 0 | 18 | 18 | 201 | 335 | 36% | 729 | 845 |
| 5.4.2.1 | 211-275 GHz Receiver LO multiplier Parts | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.2.2 | 211-275 GHz Receiver LO Multiplier Assembly & Test | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.2.3 | 275-370 GHz LO integrate source & multiplier | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.3.1 | 602-720 GHz Receiver LO multiplier Parts | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.3.2 | 602-720 GHz Receiver LO multiplier Assembly & Test | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |

# Millimeter Array Construction: 2005

US Reference Project

| WBS | Task Name | Scientists Work-months | Programmers Work-months | Engineers Work-months | Technicians Work-months | Personnel 1999 $K | Materials & Supplies 1999 $K | Contingency | Total Cost 1999 $K | Inflated Cost 2005 $K |
|---|---|---|---|---|---|---|---|---|---|---|
| 5.4.3.3 | 602-720 GHz LO integrate source & multiplier | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.4.1 | 275-370 GHz Receiver LO multiplier Parts | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.4.2 | 275-370 GHz Receiver LO multiplier Assembly & Test | 0 | 0 | 1 | 1 | 11 | 0 | 34% | 15 | 17 |
| 5.4.4.3 | 275-370 GHz LO integrate source & multiplier | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.5.1 | 163-211 GHz Receiver LO multiplier Parts | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.5.2 | 163-211 GHz Receiver LO multiplier Assembly & Test | 0 | 0 | 1 | 5 | 27 | 0 | 34% | 36 | 42 |
| 5.4.5.3 | 163-211 GHz LO integrate source & multiplier | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.6.1 | 385-500 GHz Receiver LO multiplier Parts | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.6.2 | 385-500 GHz Receiver LO multiplier Assembly & Test | 0 | 0 | 1 | 5 | 27 | 0 | 34% | 36 | 42 |
| 5.4.6.3 | 385-500 GHz LO integrate source & multiplier | 0 | 0 | 4 | 12 | 76 | 18 | 34% | 126 | 146 |
| 5.4.7.1 | 125-163 GHz Receiver LO multiplier Parts | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.7.2 | 125-163 GHz Receiver LO multiplier Assembly & Test | 0 | 0 | 1 | 7 | 35 | 0 | 34% | 46 | 54 |
| 5.4.7.3 | 125-163 GHz LO integrate source & multiplier | 0 | 0 | 2 | 6 | 38 | 10 | 34% | 64 | 74 |
| 5.4.8.1 | Design & fab 31-45 GHz receiver LO coupling | 0 | 0 | 0 | 0 | 0 | 0 | 12% | 0 | 0 |
| 5.4.9 | LO Multiplier Fabrication Equipment | 0 | 0 | 0 | 0 | 0 | 0 | 11% | 0 | 0 |
| 5.4.10 | LO Multiplier Test Equipment | 0 | 0 | 0 | 0 | 0 | 0 | 11% | 0 | 0 |
| | | | | | | | | | | |
| 6.1 | IF Field Prototype for Test Interferometer of 2 antennas. | 0 | 0 | 0 | 0 | 0 | 0 | 10% | 0 | 0 |
| 6.2 | IF Construction test & lab equipment | 0 | 0 | 0 | 0 | 0 | 0 | 5% | 0 | 0 |
| 6.3 | IF Multiplexer (2/antenna) | 0 | 0 | 6 | 12 | 90 | 506 | 20% | 715 | 829 |
| 6.4 | IF Demultiplexer (2/antenna) | 0 | 0 | 5 | 12 | 83 | 179 | 10% | 288 | 334 |
| 6.5 | IF Matrix Switch (2/antenna) | 0 | 0 | 1 | 6 | 31 | 111 | 6% | 150 | 174 |
| 6.6 | IF Baseband Converter (8/antenna) | 0 | 0 | 6 | 12 | 90 | 430 | 20% | 625 | 724 |
| 6.7 | IF Power Supply module | 0 | 0 | 0 | 1 | 4 | 14 | 5% | 19 | 22 |
| 6.8 | Bins / Racks (assemble and test) | 0 | 0 | 0 | 2 | 8 | 33 | 5% | 43 | 50 |
| | | | | | | | | | | |
| 7.1 | Prototype Optical Fiber Systems | 0 | 0 | 0 | 0 | 0 | 0 | 32% | 0 | 0 |
| 7.2 | Digital IF Transmitters and Receivers | 0 | 0 | 18 | 27 | 236 | 714 | 40% | 1,329 | 1,542 |
| 7.3.1 | 16 GHZ FO LO Ref Dist Prototype | 0 | 0 | 0 | 0 | 0 | 0 | 40% | 0 | 0 |
| 7.3.2 | 16 GHz FO LO Ref Dist with Integrated R/T Phase Meas. | 0 | 0 | 24 | 36 | 315 | 139 | 28% | 580 | 673 |
| 7.4 | Production Test Equipment | 0 | 0 | 0 | 0 | 0 | 0 | 5% | 0 | 0 |
| 7.5 | Monitor and Control Transmitters and Receivers | 0 | 0 | 5 | 12 | 83 | 44 | 14% | 145 | 168 |
| 7.6 | Fiber Optics Power Supply Modules | 0 | 0 | 2 | 4 | 30 | 15 | 14% | 52 | 60 |
| 7.7 | Bins / Racks (assemble and test) | 0 | 0 | 4 | 8 | 60 | 20 | 14% | 91 | 106 |
| | | | | | | | | | | |
| 8.1.1 | Refine digitizer design | 0 | 0 | 0 | 0 | 0 | 0 | 30% | 0 | 0 |
| 8.1.3 | Digitizer contract materials | 0 | 0 | 0 | 0 | 0 | 0 | 30% | 0 | 0 |
| 8.1.4 | Assembly of digitizers | 0 | 0 | 0 | 0 | 0 | 0 | 26% | 0 | 0 |
| 8.1.5 | Digitizer validation and delivery | 0 | 0 | 0 | 0 | 0 | 0 | 26% | 0 | 0 |
| 8.2.1 | Prototype FIR filter testing on interferometer | 0 | 0 | 0 | 0 | 0 | 0 | 38% | 0 | 0 |
| 8.2.2 | Design & test FIR filter refinement | 0 | 0 | 0 | 0 | 0 | 0 | 32% | 0 | 0 |
| 8.2.4 | FIR filter chip & board fabrication | 0 | 0 | 0 | 0 | 0 | 0 | 32% | 0 | 0 |
| 8.2.5 | FIR filter board assembly | 0 | 0 | 0 | 0 | 0 | 0 | 26% | 0 | 0 |
| 8.2.6 | FIR filter board validation and delivery | 0 | 0 | 0 | 0 | 0 | 0 | 32% | 0 | 0 |
| 8.3.1 | Correlator boards | 0 | 0 | 0 | 0 | 0 | 0 | 26% | 0 | 0 |
| 8.4 | Correlator Chip | 0 | 0 | 0 | 0 | 0 | 0 | 30% | 0 | 0 |
| 8.6 | Correlator software | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 8.5 | Correlator Racks | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 8.7 | Prototype Correlator Production | 0 | 0 | 0 | 0 | 0 | 0 | 28% | 0 | 0 |
| 8.8.1 | First 1/4 Correlator | 0 | 0 | 0 | 0 | 0 | 0 | 28% | 0 | 0 |
| 8.8.2 | Second 1/4 Correlator | 0 | 0 | 18 | 18 | 201 | 31 | 24% | 287 | 333 |
| 8.8.3 | Third 1/4 Correlator | 0 | 0 | 18 | 18 | 201 | 0 | 24% | 249 | 289 |

# Millimeter Array Construction: 2005

US Reference Project

| WBS | Task Name | Scientists Work-months | Programmers Work-months | Engineers Work-months | Technicians Work-months | Personnel 1999 $K | Materials & Supplies 1999 $K | Contingency | Total Cost 1999 $K | Inflated Cost 2005 $K |
|---|---|---|---|---|---|---|---|---|---|---|
| 8.8.4 | Fourth 1/4 Correlator | 0 | 0 | 0 | 0 | 0 | 389 | 24% | 482 | 559 |
| 8.9 | Correlator test equipment | 0 | 0 | 0 | 0 | 0 | 0 | 5% | 0 | 0 |
| | | | | | | | | | | |
| 9 | Computing | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.1 | Control Software | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.1.1 | Test Interferometer Control and Analysis | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 9.1.2 | MMA Correlator Software | 0 | 12 | 0 | 0 | 72 | 0 | 34% | 96 | 111 |
| 9.1.3 | Multi-antenna & sub-array control | 0 | 6 | 0 | 0 | 36 | 90 | 34% | 169 | 195 |
| 9.1.4 | Operators and Observers Interfaces | 0 | 0 | 0 | 0 | 0 | 5 | 34% | 7 | 8 |
| 9.1.5 | Deliver control software | 0 | 0 | 0 | 0 | 0 | 0 | 30% | 0 | 0 |
| 9.1.6 | Maintenance | 0 | 0 | 0 | 0 | 0 | 0 | 18% | 0 | 0 |
| 9.2 | Scheduling | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.2.1 | Static Scheduling System | 0 | 9 | 0 | 0 | 54 | 0 | 34% | 72 | 83 |
| 9.2.2 | Dynamic scheduling simulations | 12 | 0 | 0 | 0 | 86 | 0 | 34% | 115 | 133 |
| 9.2.3 | Dynamic scheduling prototype | 3 | 6 | 0 | 0 | 57 | 0 | 30% | 74 | 86 |
| 9.2.4 | Dynamic scheduling implementation | 0 | 0 | 0 | 0 | 0 | 0 | 39% | 0 | 0 |
| 9.3 | Proposal preparation software | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.3.1 | Proposal assistance prototype | 0 | 0 | 0 | 0 | 0 | 0 | 30% | 0 | 0 |
| 9.3.2 | Proposal assistance implementation | 3 | 6 | 0 | 0 | 57 | 0 | 30% | 74 | 86 |
| 9.3.3 | Observe program prototype | 0 | 0 | 0 | 0 | 0 | 0 | 26% | 0 | 0 |
| 9.3.4 | Observe program | 3 | 6 | 0 | 0 | 57 | 0 | 26% | 72 | 84 |
| 9.4 | Image pipeline | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.4.1 | Automated calibration & imaging heuristics | 0 | 0 | 0 | 0 | 0 | 0 | 39% | 0 | 0 |
| 9.4.2 | Prototype image pipeline | 3 | 6 | 0 | 0 | 57 | 0 | 30% | 74 | 86 |
| 9.4.3 | Parallelization studies and implementation | 0 | 12 | 0 | 0 | 72 | 0 | 34% | 96 | 111 |
| 9.4.4 | Initial image pipeline operations | 0 | 0 | 0 | 0 | 0 | 0 | 26% | 0 | 0 |
| 9.4.5 | Production image pipeline | 6 | 12 | 0 | 0 | 114 | 0 | 30% | 149 | 172 |
| 9.5 | Archiving | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.5.1 | Prototype distributed archive | 0 | 0 | 0 | 0 | 0 | 0 | 30% | 0 | 0 |
| 9.5.2 | Evaluate storage hardware | 0 | 0 | 0 | 0 | 0 | 0 | 11% | 0 | 0 |
| 9.5.3 | Production archive | 6 | 12 | 0 | 0 | 114 | 0 | 30% | 149 | 172 |
| 9.6 | Post processing | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.6.1 | Define data formats | 0 | 0 | 0 | 0 | 0 | 0 | 18% | 0 | 0 |
| 9.6.2 | Filler and format conversions | 0 | 6 | 0 | 0 | 36 | 0 | 22% | 44 | 51 |
| 9.6.3 | ALMA specific calibrations | 0 | 0 | 0 | 0 | 0 | 0 | 39% | 0 | 0 |
| 9.6.4 | MMA Post-processing begins | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.6.5 | Maintenance | 0 | 0 | 0 | 0 | 0 | 0 | 22% | 0 | 0 |
| 9.7 | Software support | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.7.1 | Tool support | 0 | 6 | 0 | 0 | 36 | 0 | 34% | 48 | 56 |
| 9.7.2 | Quality assurance | 0 | 12 | 0 | 0 | 72 | 0 | 34% | 96 | 111 |
| 9.7.3 | Chile system administration | 0 | 0 | 0 | 0 | 0 | 0 | 22% | 0 | 0 |
| | | | | | | | | | | |
| 10 | System Integration | 0 | 0 | 0 | 0 | 0 | 0 | 10% | 0 | 0 |
| 10.4 | Test Interferometer Site Preparation | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.10 | Oufitting at U.S. test site | 0 | 0 | 0 | 0 | 0 | 0 | 12% | 0 | 0 |
| 10.10.4 | Antenna #1 Outfitting | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.10.7 | Antenna #2 Outfitting | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.10.10 | General Outfitting | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.11 | Single Dish Tests | 0 | 0 | 0 | 0 | 0 | 0 | 11% | 0 | 0 |
| 10.11.1 | Ant #1 holography and surface readjustment | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.11.2 | Ant #1 Antenna Evaluation | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.11.6 | Ant #2 holography and surface readjustment | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |

# Millimeter Array Construction: 2005

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|---|---|---|---|---|---|---|---|---|---|---|
| 10.11.7 | Ant #2 Antenna Evaluation | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.12 | Interferometric Tests | 0 | 0 | 0 | 0 | 0 | 0 | 11% | 0 | 0 |
| 10.12.1 | Phase/gain stability tests | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.12.2 | Sensitivity verification | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.12.3 | Holography with astronomical sources | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.12.4 | Modifications and Retrofits | 0 | 0 | 0 | 0 | 0 | 0 | 35% | 0 | 0 |
| 10.13 | Dissassemble test system and ship to array site | 0 | 0 | 0 | 4 | 16 | 806 | 35% | 1,109 | 1,286 |
| 10.14 | On-site System Integration | 0 | 0 | 0 | 0 | 0 | 0 | 50% | 0 | 0 |
| 10.14.1 | Set up assembly and test facilities at OSF | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.14.2 | Outfit antennas 3 through 36 | 0 | 0 | 0 | 0 | 0 | 10 | 25% | 13 | 14 |
| 10.14.2.1 | Wiring and plumbing | 0 | 0 | 0 | 7 | 25 | 77 | 25% | 128 | 148 |
| 10.14.2.2 | Install electronics in receiver cabin | 0 | 0 | 0 | 7 | 25 | 77 | 25% | 128 | 148 |
| 10.14.2.3 | Check out completed antenna at OSF | 3 | 0 | 7 | 7 | 91 | 0 | 25% | 114 | 132 |
| 10.14.2.4 | Install antenna at array site. | 0 | 0 | 0 | 7 | 28 | 0 | 25% | 36 | 41 |
| 10.14.3 | Refurbish antennas 1 and 2 | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.14.3.1 | Re-install electronics and upgrade as needed | 0 | 0 | 0 | 1 | 4 | 0 | 25% | 5 | 6 |
| 10.14.3.2 | Check out at OSF | 1 | 0 | 2 | 2 | 26 | 0 | 25% | 32 | 38 |
| 10.14.3.3 | Install antenna at array site | 0 | 0 | 0 | 2 | 8 | 0 | 25% | 10 | 11 |
| 10.14.4 | Install central building electronics | 0 | 0 | 1 | 0 | 7 | 0 | 25% | 9 | 11 |
| 10.14.5 | Support debugging and repair | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.20 | Prototype Testing Support | 0 | 0 | 0 | 0 | 0 | 0 | 10% | 0 | 0 |
| | | | | | | | | | | |
| 11.1.1 | Completion of 183 GHz Water Vapor Radiometer | 0 | 0 | 0 | 0 | 0 | 0 | 11% | 0 | 0 |
| 11.1.2 | Demonstrate 183 GHz Water Vapor Radiometer | 0 | 0 | 0 | 0 | 0 | 0 | 12% | 0 | 0 |
| 11.1.3 | Refinement of 183 GHz Water Vapor Radiometer | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 11.1.4 | Release WVR for manufacture | 0 | 0 | 0 | 0 | 0 | 0 | 10% | 0 | 0 |
| 11.2.1.1 | Contract Phase Monitor Radiometer Subassembly | 0 | 0 | 0 | 0 | 0 | 0 | 10% | 0 | 0 |
| 11.2.1.2 | WVR Spectrometer | 0 | 0 | 0 | 0 | 0 | 75 | 10% | 83 | 96 |
| 11.2.1.3 | WVR Feed, Window, Lens, Instrumentation | 0 | 0 | 0 | 0 | 0 | 0 | 10% | 0 | 0 |
| 11.2.1.4 | Monitor and Control WVR Interface | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 11.2.3 | Deliver Production Radiometers | 0 | 0 | 0 | 0 | 0 | 0 | 9% | 0 | 0 |
| 11.2.4 | Integration of WVR into Receiver Package | 0 | 0 | 0 | 6 | 23 | 0 | 7% | 25 | 29 |
| 11.2.5 | Verification on Site of WVR | 0 | 0 | 0 | 3 | 12 | 0 | 9% | 13 | 15 |
| 11.3.1 | Dual-Load Amp. Calibration Device Design Refinement | 0 | 0 | 0 | 0 | 0 | 0 | 7% | 0 | 0 |
| 11.3.2 | Release Dual-Load Amp Cal for Mftr | 0 | 0 | 0 | 0 | 0 | 0 | 8% | 0 | 0 |
| 11.3.3 | Contract Subassembly Dual-Load Amp Cal | 0 | 0 | 0 | 0 | 0 | 0 | 7% | 0 | 0 |
| 11.3.3.1 | Dual-Load AmpCal Subassy Machining | 0 | 0 | 0 | 0 | 0 | 0 | 7% | 0 | 0 |
| 11.3.3.2 | Load Fabrication for Dual Load Amp Cal | 0 | 0 | 0 | 0 | 0 | 0 | 7% | 0 | 0 |
| 11.3.3.3 | Dual Load Amplitude Calibration Device Motors, Servo | 0 | 0 | 0 | 0 | 0 | 0 | 7% | 0 | 0 |
| 11.3.3.4 | M/C Interface for Dual Load Amp Cal Device | 0 | 0 | 0 | 0 | 0 | 0 | 7% | 0 | 0 |
| 11.3.4 | Assembly and Test of Dual Load Amplitude Calibration | 0 | 0 | 0 | 0 | 0 | 0 | 7% | 0 | 0 |
| 11.3.5 | Integration of AmpCal on Production Antennas | 0 | 0 | 0 | 3 | 12 | 0 | 7% | 13 | 15 |
| 11.4 | Imaging Studies and Project Support | 0 | 0 | 0 | 0 | 0 | 0 | 5% | 0 | 0 |
| 11.5 | Imaging Algorithm Development | 0 | 0 | 0 | 0 | 0 | 0 | 7% | 0 | 0 |
| | | | | | | | | | | |
| | Totals | 99 | 111 | 391 | 825 | 7,425 | 37,587 | | 56,642 | 65,592 |

# Millimeter Array Construction: 2006

US Reference Project

| WBS | Task Name | Scientists Work-months | Programmers Work-months | Engineers Work-months | Technicians Work-months | Personnel 1999 $K | Materials & Supplies 1999 $K | Contingency | Total Cost 1999 $K | Inflated Cost 2006 $K |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.1 | Project Management | 60 | 0 | 0 | 24 | 523 | 0 | 15% | 601 | 714 |
| 1.1.1 | Management, Planning, and Oversight | 0 | 0 | 0 | 0 | 0 | 705 | 15% | 811 | 964 |
| 1.1.2 | Business Operations | 0 | 0 | 0 | 0 | 0 | 100 | 15% | 115 | 137 |
| 1.1.3 | Chilean Operations | 0 | 0 | 0 | 0 | 0 | 15 | 15% | 17 | 21 |
| 1.1.4 | Safety and Health | 0 | 0 | 0 | 0 | 0 | 0 | 15% | 0 | 0 |
| 1.1.5 | Personnel | 0 | 0 | 0 | 0 | 0 | 0 | 15% | 0 | 0 |
| 1.1.6 | Project Science Office | 0 | 0 | 0 | 0 | 0 | 0 | 15% | 0 | 0 |
| 1.1.7 | AUI Management | 0 | 0 | 0 | 0 | 0 | 350 | 15% | 402 | 478 |
| 1.2 | Engineering | 0 | 0 | 24 | 12 | 221 | 20 | 15% | 277 | 329 |
| 1.2.1 | System Engineering--Phase II | 0 | 0 | 0 | 0 | 0 | 0 | 15% | 0 | 0 |
| 1.2.2 | Documentation System | 0 | 0 | 0 | 0 | 0 | 0 | 15% | 0 | 0 |
| 1.2.3 | Production Engineering | 0 | 0 | 0 | 0 | 0 | 0 | 15% | 0 | 0 |
| 1.3 | US Facilities | 0 | 0 | 0 | 0 | 0 | 0 | 15% | 0 | 0 |
| 1.3.1 | CDL Permanent Facilities | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 1.3.2 | Manufacturing Facilities | 0 | 0 | 0 | 0 | 0 | 115 | 10% | 127 | 150 |
| 1.3.3 | Common Infrastructure | 0 | 0 | 0 | 0 | 0 | 200 | 15% | 230 | 273 |
| | | | | | | | | | | |
| 2 | Site Development | 0 | 0 | 12 | 0 | 87 | 50 | 5% | 144 | 171 |
| 2.2 | Maintain Mining claims | 0 | 0 | 0 | 0 | 0 | 25 | 5% | 26 | 31 |
| 2.3 | Contract A&E Studies | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 2.5.3 | Contract Array Site Civil Works | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 2.6.3 | Contract OSF Civil Works | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 2.7.3 | Contract Civil Works | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 2.8.1 | Equip Array Site | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 2.8.2 | Equip Operations Support Facility | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| | | | | | | | | | | |
| 3.1 | Antenna Engineering Support | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 3.8.10 | Sign Transporter Contract | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 3.8.30 | Accept Transporter #2 at OSF | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 3.8.35 | Contract for Transporter #1 Move to site | 0 | 0 | 0 | 0 | 0 | 0 | 12% | 0 | 0 |
| 3.15 | Procurement of Antenna 2 | 0 | 0 | 0 | 0 | 0 | 0 | 27% | 0 | 0 |
| 3.20 | Sign Contract for Production Antennas | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 3.21 | Antenna Contract Supervision | 0 | 0 | 27 | 0 | 196 | 0 | 12% | 219 | 261 |
| 3.23 | Accept Antenna #3 at OSF | 0 | 0 | 0 | 0 | 0 | 0 | 27% | 0 | 0 |
| 3.25, 3.27, 3.2 | Accept Antennas #4 through #36 | 0 | 0 | 18 | 0 | 131 | 33,048 | 27% | 42,137 | 50,088 |
| | | | | | | | | | | |
| 4.1.1.2 | Fabricate PPRC | 0 | 0 | 0 | 0 | 0 | 0 | 28% | 0 | 0 |
| 4.1.1.3 | Test PPRC | 0 | 0 | 0 | 0 | 0 | 0 | 5% | 0 | 0 |
| 4.1.2.1 | PPR Dewar Design | 0 | 0 | 0 | 0 | 0 | 0 | 17% | 0 | 0 |
| 4.1.2.2 | PPR Dewar Fabrication and Vacuum Testing | 0 | 0 | 0 | 0 | 0 | 0 | 40% | 0 | 0 |
| 4.1.2.3 | PPR Vacuum Windows and IR Filters | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 4.1.2.4 | PPR Cryogenics/Dewar Assembly and Testing | 0 | 0 | 0 | 0 | 0 | 0 | 13% | 0 | 0 |
| 4.1.3.1 | PPR Control-Monitoring and Bias Electronics Design | 0 | 0 | 0 | 0 | 0 | 0 | 21% | 0 | 0 |
| 4.1.3.2 | PPR Control-Monitor and Bias Electronics Construction | 0 | 0 | 0 | 0 | 0 | 0 | 44% | 0 | 0 |
| 4.1.4.1 | Insert Mechanical-Thermal Design, Bands <275 GHz (Waveguid | 0 | 0 | 0 | 0 | 0 | 0 | 48% | 0 | 0 |
| 4.1.4.2 | Insert Component Fabrication for Bands <275 GHz | 0 | 0 | 0 | 0 | 0 | 0 | 56% | 0 | 0 |
| 4.1.4.3 | Insert Mechanical-Thermal Design for Bands >275 GHz (Quasi o | 0 | 0 | 0 | 0 | 0 | 0 | 48% | 0 | 0 |
| 4.1.4.4 | Insert Component Fabrication for Bands >275 Ghz | 0 | 0 | 0 | 0 | 0 | 0 | 56% | 0 | 0 |
| 4.1.4.8 | PPR Insert Assembly (3 Bands) | 0 | 0 | 0 | 0 | 0 | 0 | 44% | 0 | 0 |
| 4.1.4.9 | PPR Insert Testing (3 Bands) | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.1.5.1 | PPR Vacuum System Assembly | 0 | 0 | 0 | 0 | 0 | 0 | 8% | 0 | 0 |
| 4.1.7.1 | PPR Post IF System Design | 0 | 0 | 0 | 0 | 0 | 0 | 22% | 0 | 0 |

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| WBS | Task Name | Scientists Work-months | Programmers Work-months | Engineers Work-months | Technicians Work-months | Personnel 1999 $K | Materials & Supplies 1999 $K | Contingency | Total Cost 1999 $K | Inflated Cost 2006 $K |
|---|---|---|---|---|---|---|---|---|---|---|
| 4.1.7.2 | PPR Post IF System Construction and Testing | 0 | 0 | 0 | 0 | 0 | 0 | 24% | 0 | 0 |
| 4.1.8.1 | PPR Frame Design | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.1.8.2 | PPR Frame Fabrication | 0 | 0 | 0 | 0 | 0 | 0 | 30% | 0 | 0 |
| 4.1.9.1 | Prototype Production Receiver Integration | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.1.9.2 | PPR Testing and Evaluation | 0 | 0 | 0 | 0 | 0 | 0 | 36% | 0 | 0 |
| 4.1.10.1 | Design and build Prototype and Production Receiver Test Set | 0 | 0 | 0 | 0 | 0 | 0 | 36% | 0 | 0 |
| 4.1.10.2 | Design and Fabricate Receiver Insert Test Set | 0 | 0 | 0 | 0 | 0 | 0 | 11% | 0 | 0 |
| 4.1.10.3 | General Test Equipment | 0 | 0 | 0 | 0 | 0 | 0 | 13% | 0 | 0 |
| 4.2.1 | MMA Receiver (MMA Rx) Design Refinement | 0 | 0 | 0 | 0 | 0 | 0 | 28% | 0 | 0 |
| 4.2.2 | MMA Receiver (MMA Rx) Documentation | 0 | 0 | 0 | 0 | 0 | 0 | 18% | 0 | 0 |
| 4.2.4.1 | MMA Rx Dewar Fabrication | 0 | 0 | 1 | 9 | 42 | 63 | 16% | 122 | 145 |
| 4.2.4.2 | MMA Rx Cryogenics Fabrication | 0 | 0 | 3 | 27 | 127 | 594 | 20% | 865 | 1,029 |
| 4.2.4.3 | Vacuum Windows and IR Filters Fabrication | 0 | 0 | 2 | 11 | 57 | 27 | 16% | 98 | 117 |
| 4.2.4.4 | Receiver Insert Fabrication | 0 | 0 | 2 | 80 | 327 | 666 | 22% | 1,211 | 1,439 |
| 4.2.4.5 | MMA Receiver Frame Fabrication and assembly | 0 | 0 | 1 | 18 | 77 | 135 | 16% | 246 | 293 |
| 4.2.4.6 | Vacuum System Fabrication and testing. | 0 | 0 | 0 | 5 | 20 | 180 | 16% | 231 | 275 |
| 4.2.4.7 | Bias and Control-Monitoring Electronics Construction | 0 | 0 | 1 | 4 | 23 | 216 | 16% | 277 | 329 |
| 4.2.4.9 | Assemble Receiver Inserts and Test | 0 | 0 | 40 | 80 | 602 | 546 | 20% | 1,378 | 1,638 |
| 4.2.4.10 | Assemble MMA Rx IF System | 0 | 0 | 1 | 5 | 27 | 131 | 14% | 179 | 213 |
| 4.2.6.1 | Integrate Test & Commission MMA Receivers | 0 | 0 | 13 | 27 | 200 | 27 | 16% | 263 | 313 |
| 4.5.1 | Construct and test Cryo system for 2nd Evaluation Receiver | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.5.2 | Fabrication and assembly of 2nd Evaluation Receiver. | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.5.3 | Test and Commission 2nd Evaluation Receiver | 0 | 0 | 0 | 0 | 0 | 0 | 5% | 0 | 0 |
| 4.3.1.1 | Design, Fab, and Test 211-275 GHz Mixer Design | 0 | 0 | 0 | 0 | 0 | 0 | 52% | 0 | 0 |
| 4.3.1.3 | Fabricate 211-275 GHz mixer blocks | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.3.1.4 | Fabricate & test 211-275 GHz SIS Mixer Detector Modules | 0 | 0 | 0 | 0 | 0 | 0 | 52% | 0 | 0 |
| 4.3.2.1 | Design, Fab, and Test 602-720 GHz Mixer Design | 0 | 0 | 0 | 0 | 0 | 0 | 52% | 0 | 0 |
| 4.3.2.3 | Fabricate 602-720 GHz mixer blocks | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.3.2.4 | Fabricate & test 602-720 GHz SIS Mixer Detector Modules | 0 | 0 | 0 | 0 | 0 | 0 | 78% | 0 | 0 |
| 4.3.3.1 | Design, Fab, and Test 275-370 GHz Mixer Design | 0 | 0 | 0 | 0 | 0 | 0 | 52% | 0 | 0 |
| 4.3.3.3 | Fabricate 275-370 GHz mixer blocks | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.3.3.4 | Fabricate & test 275-370 GHz SIS Mixer Detector Modules | 0 | 0 | 0 | 0 | 0 | 0 | 52% | 0 | 0 |
| 4.3.4.1 | Design, Fab, and Test 89-116 GHz Mixer Design | 0 | 0 | 0 | 0 | 0 | 0 | 52% | 0 | 0 |
| 4.3.4.3 | Fabricate 89-116 GHz mixer blocks | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.3.4.4 | Fabricate 89-116 GHz SIS Mixer Detector Modules | 0 | 0 | 0 | 0 | 0 | 0 | 52% | 0 | 0 |
| 4.3.5.1 | Design, Fab, and Test 163-211 GHz Mixer Design | 0 | 0 | 0 | 0 | 0 | 0 | 52% | 0 | 0 |
| 4.3.5.3 | Fabricate 163-211 GHz Mixer Blocks | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.3.5.4 | Fabricate & test 163-211 GHz SIS Mixer Detector Modules | 0 | 0 | 0 | 0 | 0 | 0 | 52% | 0 | 0 |
| 4.3.6.1 | Design, Fab, and Test 385-500 GHz Mixer Design | 0 | 0 | 0 | 0 | 0 | 0 | 52% | 0 | 0 |
| 4.3.6.3 | Fabricate 385-500 GHz mixer blocks | 0 | 0 | 0 | 3 | 12 | 6 | 16% | 20 | 24 |
| 4.3.6.4 | Fabricate & Test 385-500 GHz SIS Mixer Detector Modules | 0 | 0 | 6 | 14 | 98 | 204 | 52% | 460 | 547 |
| 4.3.7.1 | Design, Fab, and Test 125-163 GHz Mixer Design | 0 | 0 | 0 | 0 | 0 | 0 | 52% | 0 | 0 |
| 4.3.7.3 | Fabricate 125-163 GHz mixer blocks | 0 | 0 | 0 | 7 | 27 | 5 | 16% | 37 | 44 |
| 4.3.7.4 | Fabricate & Test 125-163 GHz SIS Mixer Detector Modules | 0 | 0 | 12 | 29 | 200 | 344 | 34% | 729 | 867 |
| 4.3.8.1 | Build SIS Fabrication Equipment | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.3.8.2 | Build SIS Test Dewar & Rack #1 | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.3.8.3 | Build SIS Test Dewar & Rack #2 | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.3.8.4 | Build SIS Test Dewar & Rack #3 | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.3.8.5 | Build SIS Test Dewar & Rack #4 | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.3.8.6 | Build Wafer Evaluation Test Sets | 0 | 0 | 0 | 0 | 0 | 0 | 18% | 0 | 0 |
| 4.3.8.7.1 | General SIS Test Equipment | 0 | 0 | 0 | 0 | 0 | 0 | 5% | 0 | 0 |
| 4.3.8.7.2 | Equip Network Analyzer to 330 GHz | 0 | 0 | 0 | 0 | 0 | 0 | 15% | 0 | 0 |

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|---|---|---|---|---|---|---|---|---|---|---|
| 4.3.8.7.3 | Near-Field Antenna Test Equipment | 0 | 0 | 0 | 0 | 0 | 0 | 15% | 0 | 0 |
| 4.3.8.8 | Build 211-275 GHz Test Plates | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.3.8.9 | Build 602-720 GHz Test Plates | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.3.8.10 | Build 275-370 GHz Test Plates | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.3.8.11 | Build 89-116 GHz Test Plates | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.3.8.12 | Build 163-211 GHz Test Plates | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.3.8.13 | Build 385-500 GHz Test Plates | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.3.8.14 | Build 125-163 GHz Test Plates | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.3.9.1 | Obtain and evaluate InP IF amplifier wafers | 0 | 0 | 0 | 0 | 0 | 0 | 10% | 0 | 0 |
| 4.3.9.2 | Build IF amplifiers | 0 | 0 | 6 | 32 | 168 | 104 | 10% | 300 | 356 |
| 4.4.1 | Contract for HFET wafer | 0 | 0 | 0 | 0 | 0 | 0 | 24% | 0 | 0 |
| 4.4.2 | Receive and evaluate InP LNA wafer | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.4.3.1 | Build 31-45 GHz HFET Detector Modules | 0 | 0 | 0 | 0 | 0 | 0 | 10% | 0 | 0 |
| 4.4.4.1 | Design 67-90 GHz amplifier | 0 | 0 | 0 | 0 | 0 | 0 | 26% | 0 | 0 |
| 4.4.4.2 | Build 67-90 GHz HFET Detector Modules | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| | | | | | | | | | | |
| 5.1 | LO Reference: Prototype Systems | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 5.2.1 | Production test and lab equipment | 0 | 0 | 0 | 0 | 0 | 0 | 10% | 0 | 0 |
| 5.2.2 | H-maser Frequency Standard (& Rb) | 0 | 0 | 0 | 0 | 0 | 0 | 8% | 0 | 0 |
| 5.2.3 | 8 GHz PL Oscillator & Distributor | 0 | 0 | 1 | 2 | 15 | 36 | 12% | 57 | 68 |
| 5.2.4 | 10 GHz PL Oscillator & Distributor | 0 | 0 | 1 | 2 | 15 | 36 | 12% | 57 | 68 |
| 5.2.5 | 12 GHz PL Oscillator & Distributor | 0 | 0 | 1 | 2 | 15 | 36 | 12% | 57 | 68 |
| 5.2.6 | 14 GHz PL Oscillator & Distributor | 0 | 0 | 1 | 2 | 15 | 36 | 12% | 57 | 68 |
| 5.2.7 | 3.2-5.2 GHz Synthesizer | 0 | 0 | 1 | 12 | 54 | 336 | 16% | 452 | 538 |
| 5.2.8 | 3.2 -5.2 GHz PLO and Fringe Generator | 0 | 0 | 1 | 6 | 31 | 118 | 14% | 169 | 201 |
| 5.2.9 | Sampler Clock 4 GHz PL Osc & Distributor | 0 | 0 | 1 | 3 | 19 | 36 | 12% | 61 | 73 |
| 5.2.10 | LO Ref Generator | 0 | 0 | 0 | 0 | 0 | 0 | 12% | 0 | 0 |
| 5.2.11 | LO Ref Distributor - Control Bldg | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 5.2.12 | Microwave Round-trip Phase Measurement | 0 | 0 | 1 | 3 | 19 | 80 | 49% | 147 | 175 |
| 5.2.13 | 10-15 GHz Frequency Synthesizer | 0 | 0 | 1 | 6 | 31 | 71 | 49% | 151 | 180 |
| 5.2.14 | First LO Fringe Generator | 0 | 0 | 0 | 6 | 23 | 118 | 16% | 164 | 194 |
| 5.2.15 | 16 GHz PL Oscillator & Distributor | 0 | 0 | 0 | 2 | 8 | 36 | 12% | 49 | 58 |
| 5.2.16 | 26 GHz PL Oscillator & Distributor | 0 | 0 | 0 | 2 | 8 | 36 | 12% | 49 | 58 |
| 5.2.17 | LO Ref Distributor - Antenna | 0 | 0 | 0 | 2 | 8 | 48 | 18% | 65 | 78 |
| 5.2.18 | VXCO Clean-up Loop | 0 | 0 | 0 | 2 | 8 | 106 | 100% | 228 | 271 |
| 5.2.19 | Power supply module | 0 | 0 | 0 | 1 | 4 | 19 | 5% | 24 | 28 |
| 5.2.20 | Bins / Racks (assemble and test) | 0 | 0 | 0 | 0 | 0 | 11 | 14% | 13 | 15 |
| 5.3.1 | LO Source Design and System Integration | 0 | 0 | 6 | 9 | 79 | 0 | 36% | 107 | 127 |
| 5.3.2.1 | 72-95 GHz LO Source Procurement & Fabrication | 0 | 0 | 0 | 0 | 0 | 0 | 24% | 0 | 0 |
| 5.3.2.2 | 72-95 GHz LO Source Assembly & Test | 0 | 0 | 0 | 0 | 0 | 0 | 24% | 0 | 0 |
| 5.3.3.1 | 102-120 GHz LO Source Procurement & Fabrication | 0 | 0 | 0 | 0 | 0 | 0 | 24% | 0 | 0 |
| 5.3.3.2 | 102-120 GHz LO Source Assembly & Test | 0 | 0 | 0 | 0 | 0 | 0 | 24% | 0 | 0 |
| 5.3.4.1 | 87-108 GHz LO Source Procurement & Fabrication | 0 | 0 | 0 | 0 | 0 | 0 | 24% | 0 | 0 |
| 5.3.4.2 | 87-108 GHz LO Source Assembly & Test | 0 | 0 | 0 | 0 | 0 | 0 | 24% | 0 | 0 |
| 5.3.5.1 | 65-86 GHz LO Source Procurement & Fabrication | 0 | 0 | 0 | 0 | 0 | 0 | 24% | 0 | 0 |
| 5.3.5.2 | 65-86 GHz LO Source Assembly & Test | 0 | 0 | 0 | 0 | 0 | 0 | 24% | 0 | 0 |
| 5.4.1 | LO Multiplier Chain Design & System Integration | 0 | 0 | 9 | 9 | 100 | 25 | 36% | 171 | 203 |
| 5.4.2.1 | 211-275 GHz Receiver LO multiplier Parts | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.2.2 | 211-275 GHz Receiver LO Multiplier Assembly & Test | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.2.3 | 275-370 GHz LO integrate source & multiplier | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.3.1 | 602-720 GHz Receiver LO multiplier Parts | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.3.2 | 602-720 GHz Receiver LO multiplier Assembly & Test | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |

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|---|---|---|---|---|---|---|---|---|---|---|
| 5.4.3.3 | 602-720 GHz LO integrate source & multiplier | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.4.1 | 275-370 GHz Receiver LO multiplier Parts | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.4.2 | 275-370 GHz Receiver LO multiplier Assembly & Test | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.4.3 | 275-370 GHz LO integrate source & multiplier | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.5.1 | 163-211 GHz Receiver LO multiplier Parts | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.5.2 | 163-211 GHz Receiver LO multiplier Assembly & Test | 0 | 0 | 0 | 1 | 4 | 0 | 34% | 5 | 6 |
| 5.4.5.3 | 163-211 GHz LO integrate source & multiplier | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.6.1 | 385-500 GHz Receiver LO multiplier Parts | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.6.2 | 385-500 GHz Receiver LO multiplier Assembly & Test | 0 | 0 | 0 | 1 | 4 | 0 | 34% | 5 | 6 |
| 5.4.6.3 | 385-500 GHz LO integrate source & multiplier | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.7.1 | 125-163 GHz Receiver LO multiplier Parts | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.7.2 | 125-163 GHz Receiver LO multiplier Assembly & Test | 0 | 0 | 1 | 2 | 11 | 0 | 34% | 15 | 18 |
| 5.4.7.3 | 125-163 GHz LO integrate source & multiplier | 0 | 0 | 3 | 8 | 53 | 9 | 34% | 83 | 99 |
| 5.4.8.1 | Design & fab 31-45 GHz receiver LO coupling | 0 | 0 | 0 | 0 | 0 | 0 | 12% | 0 | 0 |
| 5.4.9 | LO Multiplier Fabrication Equipment | 0 | 0 | 0 | 0 | 0 | 0 | 11% | 0 | 0 |
| 5.4.10 | LO Multiplier Test Equipment | 0 | 0 | 0 | 0 | 0 | 0 | 11% | 0 | 0 |
| | | | | | | | | | | |
| 6.1 | IF Field Prototype for Test Interferometer of 2 antennas. | 0 | 0 | 0 | 0 | 0 | 0 | 10% | 0 | 0 |
| 6.2 | IF Construction test & lab equipment | 0 | 0 | 0 | 0 | 0 | 0 | 5% | 0 | 0 |
| 6.3 | IF Multiplexer (2/antenna) | 0 | 0 | 6 | 12 | 90 | 506 | 20% | 715 | 850 |
| 6.4 | IF Demultiplexer (2/antenna) | 0 | 0 | 4 | 12 | 76 | 179 | 10% | 280 | 333 |
| 6.5 | IF Matrix Switch (2/antenna) | 0 | 0 | 1 | 6 | 31 | 111 | 6% | 150 | 179 |
| 6.6 | IF Baseband Converter (8/antenna) | 0 | 0 | 6 | 12 | 90 | 430 | 20% | 625 | 742 |
| 6.7 | IF Power Supply module | 0 | 0 | 0 | 1 | 4 | 14 | 5% | 19 | 23 |
| 6.8 | Bins / Racks (assemble and test) | 0 | 0 | 0 | 2 | 8 | 33 | 5% | 43 | 51 |
| | | | | | | | | | | |
| 7.1 | Prototype Optical Fiber Systems | 0 | 0 | 0 | 0 | 0 | 0 | 32% | 0 | 0 |
| 7.2 | Digital IF Transmitters and Receivers | 0 | 0 | 18 | 24 | 224 | 714 | 40% | 1,313 | 1,561 |
| 7.3.1 | 16 GHZ FO LO Ref Dist Prototype | 0 | 0 | 0 | 0 | 0 | 0 | 40% | 0 | 0 |
| 7.3.2 | 16 GHz FO LO Ref Dist with Integrated R/T Phase Meas. | 0 | 0 | 0 | 24 | 94 | 110 | 28% | 261 | 310 |
| 7.4 | Production Test Equipment | 0 | 0 | 0 | 0 | 0 | 0 | 5% | 0 | 0 |
| 7.5 | Monitor and Control Transmitters and Receivers | 0 | 0 | 5 | 12 | 83 | 44 | 14% | 145 | 172 |
| 7.6 | Fiber Optics Power Supply Modules | 0 | 0 | 2 | 4 | 30 | 15 | 14% | 52 | 62 |
| 7.7 | Bins / Racks (assemble and test) | 0 | 0 | 4 | 8 | 60 | 20 | 14% | 91 | 108 |
| | | | | | | | | | | |
| 8.1.1 | Refine digitizer design | 0 | 0 | 0 | 0 | 0 | 0 | 30% | 0 | 0 |
| 8.1.3 | Digitizer contract materials | 0 | 0 | 0 | 0 | 0 | 0 | 30% | 0 | 0 |
| 8.1.4 | Assembly of digitizers | 0 | 0 | 0 | 0 | 0 | 0 | 26% | 0 | 0 |
| 8.1.5 | Digitizer validation and delivery | 0 | 0 | 0 | 0 | 0 | 0 | 26% | 0 | 0 |
| 8.2.1 | Prototype FIR filter testing on interferometer | 0 | 0 | 0 | 0 | 0 | 0 | 38% | 0 | 0 |
| 8.2.2 | Design & test FIR filter refinement | 0 | 0 | 0 | 0 | 0 | 0 | 32% | 0 | 0 |
| 8.2.4 | FIR filter chip & board fabrication | 0 | 0 | 0 | 0 | 0 | 0 | 32% | 0 | 0 |
| 8.2.5 | FIR filter board assembly | 0 | 0 | 0 | 0 | 0 | 0 | 26% | 0 | 0 |
| 8.2.6 | FIR filter board validation and delivery | 0 | 0 | 0 | 0 | 0 | 0 | 32% | 0 | 0 |
| 8.3.1 | Correlator boards | 0 | 0 | 0 | 0 | 0 | 0 | 26% | 0 | 0 |
| 8.4 | Correlator Chip | 0 | 0 | 0 | 0 | 0 | 0 | 30% | 0 | 0 |
| 8.6 | Correlator software | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 8.5 | Correlator Racks | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 8.7 | Prototype Correlator Production | 0 | 0 | 0 | 0 | 0 | 0 | 28% | 0 | 0 |
| 8.8.1 | First 1/4 Correlator | 0 | 0 | 0 | 0 | 0 | 0 | 28% | 0 | 0 |
| 8.8.2 | Second 1/4 Correlator | 0 | 0 | 0 | 0 | 0 | 0 | 24% | 0 | 0 |
| 8.8.3 | Third 1/4 Correlator | 0 | 0 | 0 | 0 | 0 | 10 | 24% | 12 | 15 |

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|---|---|---|---|---|---|---|---|---|---|---|
| 8.8.4 | Fourth 1/4 Correlator | 0 | 0 | 36 | 36 | 402 | 0 | 24% | 498 | 592 |
| 8.9 | Correlator test equipment | 0 | 0 | 0 | 0 | 0 | 0 | 5% | 0 | 0 |
| | | | | | | | | | | |
| 9 | Computing | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.1 | Control Software | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.1.1 | Test Interferometer Control and Analysis | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 9.1.2 | MMA Correlator Software | 0 | 12 | 0 | 0 | 72 | 0 | 34% | 96 | 114 |
| 9.1.3 | Multi-antenna & sub-array control | 0 | 6 | 0 | 0 | 36 | 110 | 34% | 195 | 232 |
| 9.1.4 | Operators and Observers Interfaces | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 9.1.5 | Deliver control software | 0 | 0 | 0 | 0 | 0 | 0 | 30% | 0 | 0 |
| 9.1.6 | Maintenance | 0 | 0 | 0 | 0 | 0 | 0 | 18% | 0 | 0 |
| 9.2 | Scheduling | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.2.1 | Static Scheduling System | 0 | 6 | 0 | 0 | 36 | 0 | 34% | 48 | 57 |
| 9.2.2 | Dynamic scheduling simulations | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 9.2.3 | Dynamic scheduling prototype | 0 | 0 | 0 | 0 | 0 | 0 | 30% | 0 | 0 |
| 9.2.4 | Dynamic scheduling implementation | 12 | 24 | 0 | 0 | 229 | 0 | 39% | 318 | 378 |
| 9.3 | Proposal preparation software | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.3.1 | Proposal assistance prototype | 0 | 0 | 0 | 0 | 0 | 0 | 30% | 0 | 0 |
| 9.3.2 | Proposal assistance implementation | 3 | 12 | 0 | 0 | 93 | 0 | 30% | 121 | 144 |
| 9.3.3 | Observe program prototype | 0 | 0 | 0 | 0 | 0 | 0 | 26% | 0 | 0 |
| 9.3.4 | Observe program | 3 | 6 | 0 | 0 | 57 | 0 | 26% | 72 | 86 |
| 9.4 | Image pipeline | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.4.1 | Automated calibration & imaging heuristics | 0 | 0 | 0 | 0 | 0 | 0 | 39% | 0 | 0 |
| 9.4.2 | Prototype image pipeline | 0 | 0 | 0 | 0 | 0 | 0 | 30% | 0 | 0 |
| 9.4.3 | Parallelization studies and implementation | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 9.4.4 | Initial image pipeline operations | 0 | 0 | 0 | 0 | 0 | 0 | 26% | 0 | 0 |
| 9.4.5 | Production image pipeline | 6 | 12 | 0 | 0 | 114 | 0 | 30% | 149 | 177 |
| 9.5 | Archiving | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.5.1 | Prototype distributed archive | 0 | 0 | 0 | 0 | 0 | 0 | 30% | 0 | 0 |
| 9.5.2 | Evaluate storage hardware | 3 | 3 | 0 | 0 | 39 | 0 | 11% | 44 | 52 |
| 9.5.3 | Production archive | 3 | 12 | 0 | 0 | 93 | 0 | 30% | 121 | 144 |
| 9.6 | Post processing | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.6.1 | Define data formats | 0 | 0 | 0 | 0 | 0 | 0 | 18% | 0 | 0 |
| 9.6.2 | Filler and format conversions | 0 | 0 | 0 | 0 | 0 | 0 | 22% | 0 | 0 |
| 9.6.3 | ALMA specific calibrations | 0 | 0 | 0 | 0 | 0 | 0 | 39% | 0 | 0 |
| 9.6.4 | MMA Post-processing begins | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.6.5 | Maintenance | 0 | 0 | 0 | 0 | 0 | 0 | 22% | 0 | 0 |
| 9.7 | Software support | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.7.1 | Tool support | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 9.7.2 | Quality assurance | 0 | 18 | 0 | 0 | 107 | 0 | 34% | 144 | 171 |
| 9.7.3 | Chile system administration | 0 | 0 | 0 | 0 | 0 | 0 | 22% | 0 | 0 |
| | | | | | | | | | | |
| 10 | System Integration | 0 | 0 | 0 | 0 | 0 | 0 | 10% | 0 | 0 |
| 10.4 | Test Interferometer Site Preparation | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.10 | Oufitting at U.S. test site | 0 | 0 | 0 | 0 | 0 | 0 | 12% | 0 | 0 |
| 10.10.4 | Antenna #1 Outfitting | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.10.7 | Antenna #2 Outfitting | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.10.10 | General Outfitting | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.11 | Single Dish Tests | 0 | 0 | 0 | 0 | 0 | 0 | 11% | 0 | 0 |
| 10.11.1 | Ant #1 holography and surface readjustment | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.11.2 | Ant #1 Antenna Evaluation | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.11.6 | Ant #2 holography and surface readjustment | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |

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|---|---|---|---|---|---|---|---|---|---|---|
| 10.11.7 | Ant #2 Antenna Evaluation | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.12 | Interferometric Tests | 0 | 0 | 0 | 0 | 0 | 0 | 11% | 0 | 0 |
| 10.12.1 | Phase/gain stability tests | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.12.2 | Sensitivity verification | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.12.3 | Holography with astronomical sources | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.12.4 | Modifications and Retrofits | 0 | 0 | 0 | 0 | 0 | 0 | 35% | 0 | 0 |
| 10.13 | Dissassemble test system and ship to array site | 0 | 0 | 0 | 0 | 0 | 0 | 35% | 0 | 0 |
| 10.14 | On-site System Integration | 0 | 0 | 0 | 0 | 0 | 0 | 50% | 0 | 0 |
| 10.14.1 | Set up assembly and test facilities at OSF | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.14.2 | Outfit antennas 3 through 36 | 0 | 0 | 0 | 0 | 0 | 10 | 25% | 13 | 15 |
| 10.14.2.1 | Wiring and plumbing | 0 | 0 | 0 | 7 | 25 | 77 | 25% | 128 | 152 |
| 10.14.2.2 | Install electronics in receiver cabin | 0 | 0 | 0 | 7 | 25 | 77 | 25% | 128 | 152 |
| 10.14.2.3 | Check out completed antenna at OSF | 2 | 0 | 7 | 7 | 84 | 0 | 25% | 105 | 125 |
| 10.14.2.4 | Install antenna at array site. | 0 | 0 | 0 | 7 | 28 | 0 | 25% | 36 | 42 |
| 10.14.3 | Refurbish antennas 1 and 2 | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.14.3.1 | Re-install electronics and upgrade as needed | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.14.3.2 | Check out at OSF | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.14.3.3 | Install antenna at array site | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.14.4 | Install central building electronics | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.14.5 | Support debugging and repair | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.20 | Prototype Testing Support | 0 | 0 | 0 | 0 | 0 | 0 | 10% | 0 | 0 |
| | | | | | | | | | | |
| 11.1.1 | Completion of 183 GHz Water Vapor Radiometer | 0 | 0 | 0 | 0 | 0 | 0 | 11% | 0 | 0 |
| 11.1.2 | Demonstrate 183 GHz Water Vapor Radiometer | 0 | 0 | 0 | 0 | 0 | 0 | 12% | 0 | 0 |
| 11.1.3 | Refinement of 183 GHz Water Vapor Radiometer | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 11.1.4 | Release WVR for manufacture | 0 | 0 | 0 | 0 | 0 | 0 | 10% | 0 | 0 |
| 11.2.1.1 | Contract Phase Monitor Radiometer Subassembly | 0 | 0 | 0 | 0 | 0 | 0 | 10% | 0 | 0 |
| 11.2.1.2 | WVR Spectrometer | 0 | 0 | 0 | 0 | 0 | 0 | 10% | 0 | 0 |
| 11.2.1.3 | WVR Feed, Window, Lens, Instrumentation | 0 | 0 | 0 | 0 | 0 | 0 | 10% | 0 | 0 |
| 11.2.1.4 | Monitor and Control WVR Interface | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 11.2.3 | Deliver Production Radiometers | 0 | 0 | 0 | 0 | 0 | 0 | 9% | 0 | 0 |
| 11.2.4 | Integration of WVR into Receiver Package | 0 | 0 | 0 | 0 | 0 | 0 | 7% | 0 | 0 |
| 11.2.5 | Verification on Site of WVR | 0 | 0 | 0 | 0 | 0 | 0 | 9% | 0 | 0 |
| 11.3.1 | Dual-Load Amp. Calibration Device Design Refinement | 0 | 0 | 0 | 0 | 0 | 0 | 7% | 0 | 0 |
| 11.3.2 | Release Dual-Load Amp Cal for Mftr | 0 | 0 | 0 | 0 | 0 | 0 | 8% | 0 | 0 |
| 11.3.3 | Contract Subassembly Dual-Load Amp Cal | 0 | 0 | 0 | 0 | 0 | 0 | 7% | 0 | 0 |
| 11.3.3.1 | Dual-Load AmpCal Subassy Machining | 0 | 0 | 0 | 0 | 0 | 0 | 7% | 0 | 0 |
| 11.3.3.2 | Load Fabrication for Dual Load Amp Cal | 0 | 0 | 0 | 0 | 0 | 0 | 7% | 0 | 0 |
| 11.3.3.3 | Dual Load Amplitude Calibration Device Motors, Servo | 0 | 0 | 0 | 0 | 0 | 0 | 7% | 0 | 0 |
| 11.3.3.4 | M/C Interface for Dual Load Amp Cal Device | 0 | 0 | 0 | 0 | 0 | 0 | 7% | 0 | 0 |
| 11.3.4 | Assembly and Test of Dual Load Amplitude Calibration | 0 | 0 | 0 | 0 | 0 | 0 | 7% | 0 | 0 |
| 11.3.5 | Integration of AmpCal on Production Antennas | 0 | 0 | 0 | 3 | 12 | 0 | 7% | 13 | 15 |
| 11.4 | Imaging Studies and Project Support | 0 | 0 | 0 | 0 | 0 | 0 | 5% | 0 | 0 |
| 11.5 | Imaging Algorithm Development | 0 | 0 | 0 | 0 | 0 | 0 | 7% | 0 | 0 |
| | | | | | | | | | | |
| | Totals | 92 | 111 | 285 | 653 | 5,931 | 41,524 | | 59,642 | 70,895 |

# Millimeter Array Construction: 2007

US Reference Project

| WBS | Task Name | Scientists Work-months | Programmers Work-months | Engineers Work-months | Technicians Work-months | Personnel 1999 $K | Materials & Supplies 1999 $K | Contingency | Total Cost 1999 $K | Inflated Cost 2007 $K |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.1 | Project Management | 60 | 0 | 0 | 24 | 523 | 0 | 15% | 601 | 732 |
| 1.1.1 | Management, Planning, and Oversight | 0 | 0 | 0 | 0 | 0 | 705 | 15% | 811 | 988 |
| 1.1.2 | Business Operations | 0 | 0 | 0 | 0 | 0 | 100 | 15% | 115 | 140 |
| 1.1.3 | Chilean Operations | 0 | 0 | 0 | 0 | 0 | 15 | 15% | 17 | 21 |
| 1.1.4 | Safety and Health | 0 | 0 | 0 | 0 | 0 | 0 | 15% | 0 | 0 |
| 1.1.5 | Personnel | 0 | 0 | 0 | 0 | 0 | 0 | 15% | 0 | 0 |
| 1.1.6 | Project Science Office | 0 | 0 | 0 | 0 | 0 | 0 | 15% | 0 | 0 |
| 1.1.7 | AUI Management | 0 | 0 | 0 | 0 | 0 | 350 | 15% | 402 | 490 |
| 1.2 | Engineering | 0 | 0 | 24 | 12 | 221 | 20 | 15% | 277 | 338 |
| 1.2.1 | System Engineering--Phase II | 0 | 0 | 0 | 0 | 0 | 0 | 15% | 0 | 0 |
| 1.2.2 | Documentation System | 0 | 0 | 0 | 0 | 0 | 0 | 15% | 0 | 0 |
| 1.2.3 | Production Engineering | 0 | 0 | 0 | 0 | 0 | 0 | 15% | 0 | 0 |
| 1.3 | US Facilities | 0 | 0 | 0 | 0 | 0 | 0 | 15% | 0 | 0 |
| 1.3.1 | CDL Permanent Facilities | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 1.3.2 | Manufacturing Facilities | 0 | 0 | 0 | 0 | 0 | 115 | 10% | 127 | 154 |
| 1.3.3 | Common Infrastructure | 0 | 0 | 0 | 0 | 0 | 200 | 15% | 230 | 280 |
| | | | | | | | | | | |
| 2 | Site Development | 0 | 0 | 12 | 0 | 87 | 50 | 5% | 144 | 175 |
| 2.2 | Maintain Mining claims | 0 | 0 | 0 | 0 | 0 | 0 | 5% | 0 | 0 |
| 2.3 | Contract A&E Studies | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 2.5.3 | Contract Array Site Civil Works | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 2.6.3 | Contract OSF Civil Works | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 2.7.3 | Contract Civil Works | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 2.8.1 | Equip Array Site | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 2.8.2 | Equip Operations Support Facility | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| | | | | | | | | | | |
| 3.1 | Antenna Engineering Support | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 3.8.10 | Sign Transporter Contract | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 3.8.30 | Accept Transporter #2 at OSF | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 3.8.35 | Contract for Transporter #1 Move to site | 0 | 0 | 0 | 0 | 0 | 0 | 12% | 0 | 0 |
| 3.15 | Procurement of Antenna 2 | 0 | 0 | 0 | 0 | 0 | 0 | 27% | 0 | 0 |
| 3.20 | Sign Contract for Production Antennas | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 3.21 | Antenna Contract Supervision | 0 | 0 | 0 | 0 | 0 | 0 | 12% | 0 | 0 |
| 3.23 | Accept Antenna #3 at OSF | 0 | 0 | 0 | 0 | 0 | 0 | 27% | 0 | 0 |
| 3.25, 3.27, 3.2 | Accept Antennas #4 through #36 | 0 | 0 | 14 | 0 | 98 | 24,786 | 27% | 31,603 | 38,505 |
| | | | | | | | | | | |
| 4.1.1.2 | Fabricate PPRC | 0 | 0 | 0 | 0 | 0 | 0 | 28% | 0 | 0 |
| 4.1.1.3 | Test PPRC | 0 | 0 | 0 | 0 | 0 | 0 | 5% | 0 | 0 |
| 4.1.2.1 | PPR Dewar Design | 0 | 0 | 0 | 0 | 0 | 0 | 17% | 0 | 0 |
| 4.1.2.2 | PPR Dewar Fabrication and Vacuum Testing | 0 | 0 | 0 | 0 | 0 | 0 | 40% | 0 | 0 |
| 4.1.2.3 | PPR Vacuum Windows and IR Filters | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 4.1.2.4 | PPR Cryogenics/Dewar Assembly and Testing | 0 | 0 | 0 | 0 | 0 | 0 | 13% | 0 | 0 |
| 4.1.3.1 | PPR Control-Monitoring and Bias Electronics Design | 0 | 0 | 0 | 0 | 0 | 0 | 21% | 0 | 0 |
| 4.1.3.2 | PPR Control-Monitor and Bias Electronics Construction | 0 | 0 | 0 | 0 | 0 | 0 | 44% | 0 | 0 |
| 4.1.4.1 | Insert Mechanical-Thermal Design, Bands <275 GHz (Waveguide | 0 | 0 | 0 | 0 | 0 | 0 | 48% | 0 | 0 |
| 4.1.4.2 | Insert Component Fabrication for Bands <275 GHz | 0 | 0 | 0 | 0 | 0 | 0 | 56% | 0 | 0 |
| 4.1.4.3 | Insert Mechanical-Thermal Design for Bands >275 GHz (Quasi o | 0 | 0 | 0 | 0 | 0 | 0 | 48% | 0 | 0 |
| 4.1.4.4 | Insert Component Fabrication for Bands >275 Ghz | 0 | 0 | 0 | 0 | 0 | 0 | 56% | 0 | 0 |
| 4.1.4.8 | PPR Insert Assembly (3 Bands) | 0 | 0 | 0 | 0 | 0 | 0 | 44% | 0 | 0 |
| 4.1.4.9 | PPR Insert Testing (3 Bands) | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.1.5.1 | PPR Vacuum System Assembly | 0 | 0 | 0 | 0 | 0 | 0 | 8% | 0 | 0 |
| 4.1.7.1 | PPR Post IF System Design | 0 | 0 | 0 | 0 | 0 | 0 | 22% | 0 | 0 |

# Millimeter Array Construction: 2007

US Reference Project

| WBS | Task Name | Scientists Work-months | Programmers Work-months | Engineers Work-months | Technicians Work-months | Personnel 1999 $K | Materials & Supplies 1999 $K | Contingency | Total Cost 1999 $K | Inflated Cost 2007 $K |
|---|---|---|---|---|---|---|---|---|---|---|
| 4.1.7.2 | PPR Post IF System Construction and Testing | 0 | 0 | 0 | 0 | 0 | 0 | 24% | 0 | 0 |
| 4.1.8.1 | PPR Frame Design | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.1.8.2 | PPR Frame Fabrication | 0 | 0 | 0 | 0 | 0 | 0 | 30% | 0 | 0 |
| 4.1.9.1 | Prototype Production Receiver Integration | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.1.9.2 | PPR Testing and Evaluation | 0 | 0 | 0 | 0 | 0 | 0 | 36% | 0 | 0 |
| 4.1.10.1 | Design and build Prototype and Production Receiver Test Set | 0 | 0 | 0 | 0 | 0 | 0 | 36% | 0 | 0 |
| 4.1.10.2 | Design and Fabricate Receiver Insert Test Set | 0 | 0 | 0 | 0 | 0 | 0 | 11% | 0 | 0 |
| 4.1.10.3 | General Test Equipment | 0 | 0 | 0 | 0 | 0 | 0 | 13% | 0 | 0 |
| 4.2.1 | MMA Receiver (MMA Rx) Design Refinement | 0 | 0 | 0 | 0 | 0 | 0 | 28% | 0 | 0 |
| 4.2.2 | MMA Receiver (MMA Rx) Documentation | 0 | 0 | 0 | 0 | 0 | 0 | 18% | 0 | 0 |
| 4.2.4.1 | MMA Rx Dewar Fabrication | 0 | 0 | 1 | 4 | 23 | 21 | 16% | 51 | 62 |
| 4.2.4.2 | MMA Rx Cryogenics Fabrication | 0 | 0 | 1 | 12 | 54 | 198 | 20% | 302 | 369 |
| 4.2.4.3 | Vacuum Windows and IR Filters Fabrication | 0 | 0 | 2 | 11 | 57 | 0 | 16% | 67 | 81 |
| 4.2.4.4 | Receiver Insert Fabrication | 0 | 0 | 2 | 50 | 210 | 396 | 22% | 739 | 900 |
| 4.2.4.5 | MMA Receiver Frame Fabrication and assembly | 0 | 0 | 1 | 8 | 38 | 45 | 16% | 97 | 118 |
| 4.2.4.6 | Vacuum System Fabrication and testing. | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.2.4.7 | Bias and Control-Monitoring Electronics Construction | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.2.4.9 | Assemble Receiver Inserts and Test | 0 | 0 | 25 | 50 | 376 | 44 | 20% | 505 | 615 |
| 4.2.4.10 | Assemble MMA Rx IF System | 0 | 0 | 1 | 2 | 15 | 44 | 14% | 67 | 81 |
| 4.2.6.1 | Integrate Test & Commission MMA Receivers | 0 | 0 | 6 | 12 | 90 | 9 | 16% | 115 | 140 |
| 4.5.1 | Construct and test Cryo system for 2nd Evaluation Receiver | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.5.2 | Fabrication and assembly of 2nd Evaluation Receiver. | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.5.3 | Test and Commission 2nd Evaluation Receiver | 0 | 0 | 0 | 0 | 0 | 0 | 5% | 0 | 0 |
| 4.3.1.1 | Design, Fab, and Test 211-275 GHz Mixer Design | 0 | 0 | 0 | 0 | 0 | 0 | 52% | 0 | 0 |
| 4.3.1.3 | Fabricate 211-275 GHz mixer blocks | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.3.1.4 | Fabricate & test 211-275 GHz SIS Mixer Detector Modules | 0 | 0 | 0 | 0 | 0 | 0 | 52% | 0 | 0 |
| 4.3.2.1 | Design, Fab, and Test 602-720 GHz Mixer Design | 0 | 0 | 0 | 0 | 0 | 0 | 52% | 0 | 0 |
| 4.3.2.3 | Fabricate 602-720 GHz mixer blocks | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.3.2.4 | Fabricate & test 602-720 GHz SIS Mixer Detector Modules | 0 | 0 | 0 | 0 | 0 | 0 | 78% | 0 | 0 |
| 4.3.3.1 | Design, Fab, and Test 275-370 GHz Mixer Design | 0 | 0 | 0 | 0 | 0 | 0 | 52% | 0 | 0 |
| 4.3.3.3 | Fabricate 275-370 GHz mixer blocks | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.3.3.4 | Fabricate & test 275-370 GHz SIS Mixer Detector Modules | 0 | 0 | 0 | 0 | 0 | 0 | 52% | 0 | 0 |
| 4.3.4.1 | Design, Fab, and Test 89-116 GHz Mixer Design | 0 | 0 | 0 | 0 | 0 | 0 | 52% | 0 | 0 |
| 4.3.4.3 | Fabricate 89-116 GHz mixer blocks | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.3.4.4 | Fabricate 89-116 GHz SIS Mixer Detector Modules | 0 | 0 | 0 | 0 | 0 | 0 | 52% | 0 | 0 |
| 4.3.5.1 | Design, Fab, and Test 163-211 GHz Mixer Design | 0 | 0 | 0 | 0 | 0 | 0 | 52% | 0 | 0 |
| 4.3.5.3 | Fabricate 163-211 GHz Mixer Blocks | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.3.5.4 | Fabricate & test 163-211 GHz SIS Mixer Detector Modules | 0 | 0 | 0 | 0 | 0 | 0 | 52% | 0 | 0 |
| 4.3.6.1 | Design, Fab, and Test 385-500 GHz Mixer Design | 0 | 0 | 0 | 0 | 0 | 0 | 52% | 0 | 0 |
| 4.3.6.3 | Fabricate 385-500 GHz mixer blocks | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.3.6.4 | Fabricate & Test 385-500 GHz SIS Mixer Detector Modules | 0 | 0 | 0 | 0 | 0 | 0 | 52% | 0 | 0 |
| 4.3.7.1 | Design, Fab, and Test 125-163 GHz Mixer Design | 0 | 0 | 0 | 0 | 0 | 0 | 52% | 0 | 0 |
| 4.3.7.3 | Fabricate 125-163 GHz mixer blocks | 0 | 0 | 0 | 1 | 4 | 1 | 16% | 6 | 7 |
| 4.3.7.4 | Fabricate & Test 125-163 GHz SIS Mixer Detector Modules | 0 | 0 | 4 | 10 | 68 | 124 | 34% | 258 | 314 |
| 4.3.8.1 | Build SIS Fabrication Equipment | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.3.8.2 | Build SIS Test Dewar & Rack #1 | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.3.8.3 | Build SIS Test Dewar & Rack #2 | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.3.8.4 | Build SIS Test Dewar & Rack #3 | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.3.8.5 | Build SIS Test Dewar & Rack #4 | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.3.8.6 | Build Wafer Evaluation Test Sets | 0 | 0 | 0 | 0 | 0 | 0 | 18% | 0 | 0 |
| 4.3.8.7.1 | General SIS Test Equipment | 0 | 0 | 0 | 0 | 0 | 0 | 5% | 0 | 0 |
| 4.3.8.7.2 | Equip Network Analyzer to 330 GHz | 0 | 0 | 0 | 0 | 0 | 0 | 15% | 0 | 0 |

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US Reference Project

| WBS | Task Name | Scientists Work-months | Programmers Work-months | Engineers Work-months | Technicians Work-months | Personnel 1999 $K | Materials & Supplies 1999 $K | Contingency | Total Cost 1999 $K | Inflated Cost 2007 $K |
|---|---|---|---|---|---|---|---|---|---|---|
| 4.3.8.7.3 | Near-Field Antenna Test Equipment | 0 | 0 | 0 | 0 | 0 | 0 | 15% | 0 | 0 |
| 4.3.8.8 | Build 211-275 GHz Test Plates | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.3.8.9 | Build 602-720 GHz Test Plates | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.3.8.10 | Build 275-370 GHz Test Plates | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.3.8.11 | Build 89-116 GHz Test Plates | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.3.8.12 | Build 163-211 GHz Test Plates | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.3.8.13 | Build 385-500 GHz Test Plates | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.3.8.14 | Build 125-163 GHz Test Plates | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 4.3.9.1 | Obtain and evaluate InP IF amplifier wafers | 0 | 0 | 0 | 0 | 0 | 0 | 10% | 0 | 0 |
| 4.3.9.2 | Build IF amplifiers | 0 | 0 | 6 | 24 | 137 | 36 | 10% | 190 | 232 |
| 4.4.1 | Contract for HFET wafer | 0 | 0 | 0 | 0 | 0 | 0 | 24% | 0 | 0 |
| 4.4.2 | Receive and evaluate InP LNA wafer | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 4.4.3.1 | Build 31-45 GHz HFET Detector Modules | 0 | 0 | 0 | 0 | 0 | 0 | 10% | 0 | 0 |
| 4.4.4.1 | Design 67-90 GHz amplifier | 0 | 0 | 0 | 0 | 0 | 0 | 26% | 0 | 0 |
| 4.4.4.2 | Build 67-90 GHz HFET Detector Modules | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| | | | | | | | | | | |
| 5.1 | LO Reference: Prototype Systems | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 5.2.1 | Production test and lab equipment | 0 | 0 | 0 | 0 | 0 | 0 | 10% | 0 | 0 |
| 5.2.2 | H-maser Frequency Standard (& Rb) | 0 | 0 | 0 | 0 | 0 | 0 | 8% | 0 | 0 |
| 5.2.3 | 8 GHz PL Oscillator & Distributor | 0 | 0 | 2 | 2 | 22 | 10 | 12% | 36 | 44 |
| 5.2.4 | 10 GHz PL Oscillator & Distributor | 0 | 0 | 2 | 2 | 22 | 10 | 12% | 36 | 44 |
| 5.2.5 | 12 GHz PL Oscillator & Distributor | 0 | 0 | 2 | 2 | 22 | 10 | 12% | 36 | 44 |
| 5.2.6 | 14 GHz PL Oscillator & Distributor | 0 | 0 | 2 | 2 | 22 | 10 | 12% | 36 | 44 |
| 5.2.7 | 3.2-5.2 GHz Synthesizer | 0 | 0 | 4 | 4 | 45 | 96 | 16% | 163 | 199 |
| 5.2.8 | 3.2 -5.2 GHz PLO and Fringe Generator | 0 | 0 | 2 | 2 | 22 | 34 | 14% | 64 | 78 |
| 5.2.9 | Sampler Clock 4 GHz PL Osc & Distributor | 0 | 0 | 2 | 1 | 18 | 10 | 12% | 32 | 39 |
| 5.2.10 | LO Ref Generator | 0 | 0 | 0 | 0 | 0 | 15 | 12% | 17 | 21 |
| 5.2.11 | LO Ref Distributor - Control Bldg | 0 | 0 | 0 | 0 | 0 | 22 | 14% | 25 | 30 |
| 5.2.12 | Microwave Round-trip Phase Measurement | 0 | 0 | 1 | 2 | 15 | 23 | 49% | 56 | 69 |
| 5.2.13 | 10-15 GHz Frequency Synthesizer | 0 | 0 | 2 | 2 | 22 | 20 | 49% | 63 | 77 |
| 5.2.14 | First LO Fringe Generator | 0 | 0 | 2 | 2 | 22 | 34 | 16% | 65 | 79 |
| 5.2.15 | 16 GHz PL Oscillator & Distributor | 0 | 0 | 2 | 2 | 22 | 10 | 12% | 36 | 44 |
| 5.2.16 | 26 GHz PL Oscillator & Distributor | 0 | 0 | 2 | 2 | 22 | 10 | 12% | 36 | 44 |
| 5.2.17 | LO Ref Distributor - Antenna | 0 | 0 | 2 | 2 | 22 | 14 | 18% | 42 | 52 |
| 5.2.18 | VXCO Clean-up Loop | 0 | 0 | 2 | 2 | 22 | 30 | 100% | 105 | 128 |
| 5.2.19 | Power supply module | 0 | 0 | 2 | 2 | 22 | 5 | 5% | 29 | 35 |
| 5.2.20 | Bins / Racks (assemble and test) | 0 | 0 | 0 | 0 | 0 | 3 | 14% | 4 | 4 |
| 5.3.1 | LO Source Design and System Integration | 0 | 0 | 0 | 0 | 0 | 0 | 36% | 0 | 0 |
| 5.3.2.1 | 72-95 GHz LO Source Procurement & Fabrication | 0 | 0 | 0 | 0 | 0 | 0 | 24% | 0 | 0 |
| 5.3.2.2 | 72-95 GHz LO Source Assembly & Test | 0 | 0 | 0 | 0 | 0 | 0 | 24% | 0 | 0 |
| 5.3.3.1 | 102-120 GHz LO Source Procurement & Fabrication | 0 | 0 | 0 | 0 | 0 | 0 | 24% | 0 | 0 |
| 5.3.3.2 | 102-120 GHz LO Source Assembly & Test | 0 | 0 | 0 | 0 | 0 | 0 | 24% | 0 | 0 |
| 5.3.4.1 | 87-108 GHz LO Source Procurement & Fabrication | 0 | 0 | 0 | 0 | 0 | 0 | 24% | 0 | 0 |
| 5.3.4.2 | 87-108 GHz LO Source Assembly & Test | 0 | 0 | 0 | 0 | 0 | 0 | 24% | 0 | 0 |
| 5.3.5.1 | 65-86 GHz LO Source Procurement & Fabrication | 0 | 0 | 0 | 0 | 0 | 0 | 24% | 0 | 0 |
| 5.3.5.2 | 65-86 GHz LO Source Assembly & Test | 0 | 0 | 0 | 0 | 0 | 0 | 24% | 0 | 0 |
| 5.4.1 | LO Multiplier Chain Design & System Integration | 0 | 0 | 0 | 0 | 0 | 25 | 36% | 34 | 41 |
| 5.4.2.1 | 211-275 GHz Receiver LO multiplier Parts | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.2.2 | 211-275 GHz Receiver LO Multiplier Assembly & Test | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.2.3 | 275-370 GHz LO integrate source & multiplier | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.3.1 | 602-720 GHz Receiver LO multiplier Parts | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.3.2 | 602-720 GHz Receiver LO multiplier Assembly & Test | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |

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|---|---|---|---|---|---|---|---|---|---|---|
| 5.4.3.3 | 602-720 GHz LO integrate source & multiplier | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.4.1 | 275-370 GHz Receiver LO multiplier Parts | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.4.2 | 275-370 GHz Receiver LO multiplier Assembly & Test | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.4.3 | 275-370 GHz LO integrate source & multiplier | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.5.1 | 163-211 GHz Receiver LO multiplier Parts | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.5.2 | 163-211 GHz Receiver LO multiplier Assembly & Test | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.5.3 | 163-211 GHz LO integrate source & multiplier | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.6.1 | 385-500 GHz Receiver LO multiplier Parts | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.6.2 | 385-500 GHz Receiver LO multiplier Assembly & Test | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.6.3 | 385-500 GHz LO integrate source & multiplier | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.7.1 | 125-163 GHz Receiver LO multiplier Parts | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.7.2 | 125-163 GHz Receiver LO multiplier Assembly & Test | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.7.3 | 125-163 GHz LO integrate source & multiplier | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 5.4.8.1 | Design & fab 31-45 GHz receiver LO coupling | 0 | 0 | 0 | 0 | 0 | 0 | 12% | 0 | 0 |
| 5.4.9 | LO Multiplier Fabrication Equipment | 0 | 0 | 0 | 0 | 0 | 0 | 11% | 0 | 0 |
| 5.4.10 | LO Multiplier Test Equipment | 0 | 0 | 0 | 0 | 0 | 0 | 11% | 0 | 0 |
| | | | | | | | | | | |
| 6.1 | IF Field Prototype for Test Interferometer of 2 antennas. | 0 | 0 | 0 | 0 | 0 | 0 | 10% | 0 | 0 |
| 6.2 | IF Construction test & lab equipment | 0 | 0 | 0 | 0 | 0 | 0 | 5% | 0 | 0 |
| 6.3 | IF Multiplexer (2/antenna) | 0 | 0 | 5 | 11 | 79 | 144 | 20% | 268 | 327 |
| 6.4 | IF Demultiplexer (2/antenna) | 0 | 0 | 4 | 8 | 60 | 51 | 10% | 122 | 149 |
| 6.5 | IF Matrix Switch (2/antenna) | 0 | 0 | 1 | 3 | 19 | 32 | 6% | 54 | 65 |
| 6.6 | IF Baseband Converter (8/antenna) | 0 | 0 | 5 | 11 | 79 | 123 | 20% | 242 | 295 |
| 6.7 | IF Power Supply module | 0 | 0 | 0 | 0 | 0 | 4 | 5% | 4 | 5 |
| 6.8 | Bins / Racks (assemble and test) | 0 | 0 | 0 | 0 | 0 | 1 | 5% | 1 | 1 |
| | | | | | | | | | | |
| 7.1 | Prototype Optical Fiber Systems | 0 | 0 | 0 | 0 | 0 | 0 | 32% | 0 | 0 |
| 7.2 | Digital IF Transmitters and Receivers | 0 | 0 | 12 | 18 | 157 | 15 | 40% | 242 | 295 |
| 7.3.1 | 16 GHZ FO LO Ref Dist Prototype | 0 | 0 | 0 | 0 | 0 | 0 | 40% | 0 | 0 |
| 7.3.2 | 16 GHz FO LO Ref Dist with Integrated R/T Phase Meas. | 0 | 0 | 0 | 24 | 94 | 31 | 28% | 160 | 195 |
| 7.4 | Production Test Equipment | 0 | 0 | 0 | 0 | 0 | 0 | 5% | 0 | 0 |
| 7.5 | Monitor and Control Transmitters and Receivers | 0 | 0 | 5 | 12 | 83 | 16 | 14% | 113 | 138 |
| 7.6 | Fiber Optics Power Supply Modules | 0 | 0 | 1 | 4 | 23 | 5 | 14% | 32 | 39 |
| 7.7 | Bins / Racks (assemble and test) | 0 | 0 | 4 | 8 | 60 | 6 | 14% | 75 | 91 |
| | | | | | | | | | | |
| 8.1.1 | Refine digitizer design | 0 | 0 | 0 | 0 | 0 | 0 | 30% | 0 | 0 |
| 8.1.3 | Digitizer contract materials | 0 | 0 | 0 | 0 | 0 | 0 | 30% | 0 | 0 |
| 8.1.4 | Assembly of digitizers | 0 | 0 | 0 | 0 | 0 | 0 | 26% | 0 | 0 |
| 8.1.5 | Digitizer validation and delivery | 0 | 0 | 0 | 0 | 0 | 0 | 26% | 0 | 0 |
| 8.2.1 | Prototype FIR filter testing on interferometer | 0 | 0 | 0 | 0 | 0 | 0 | 38% | 0 | 0 |
| 8.2.2 | Design & test FIR filter refinement | 0 | 0 | 0 | 0 | 0 | 0 | 32% | 0 | 0 |
| 8.2.4 | FIR filter chip & board fabrication | 0 | 0 | 0 | 0 | 0 | 0 | 32% | 0 | 0 |
| 8.2.5 | FIR filter board assembly | 0 | 0 | 0 | 0 | 0 | 0 | 26% | 0 | 0 |
| 8.2.6 | FIR filter board validation and delivery | 0 | 0 | 0 | 0 | 0 | 0 | 32% | 0 | 0 |
| 8.3.1 | Correlator boards | 0 | 0 | 0 | 0 | 0 | 0 | 26% | 0 | 0 |
| 8.4 | Correlator Chip | 0 | 0 | 0 | 0 | 0 | 0 | 30% | 0 | 0 |
| 8.6 | Correlator software | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 8.5 | Correlator Racks | 0 | 0 | 0 | 0 | 0 | 0 | 20% | 0 | 0 |
| 8.7 | Prototype Correlator Production | 0 | 0 | 0 | 0 | 0 | 0 | 28% | 0 | 0 |
| 8.8.1 | First 1/4 Correlator | 0 | 0 | 0 | 0 | 0 | 0 | 28% | 0 | 0 |
| 8.8.2 | Second 1/4 Correlator | 0 | 0 | 0 | 0 | 0 | 0 | 24% | 0 | 0 |
| 8.8.3 | Third 1/4 Correlator | 0 | 0 | 0 | 0 | 0 | 0 | 24% | 0 | 0 |

# Millimeter Array Construction: 2007

US Reference Project

| WBS | Task Name | Scientists Work-months | Programmers Work-months | Engineers Work-months | Technicians Work-months | Personnel 1999 $K | Materials & Supplies 1999 $K | Contingency | Total Cost 1999 $K | Inflated Cost 2007 $K |
|---|---|---|---|---|---|---|---|---|---|---|
| 8.8.4 | Fourth 1/4 Correlator | 0 | 0 | 0 | 0 | 0 | 0 | 24% | 0 | 0 |
| 8.9 | Correlator test equipment | 0 | 0 | 0 | 0 | 0 | 0 | 5% | 0 | 0 |
| | | | | | | | | | | |
| 9 | Computing | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.1 | Control Software | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.1.1 | Test Interferometer Control and Analysis | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 9.1.2 | MMA Correlator Software | 0 | 12 | 0 | 0 | 72 | 0 | 34% | 96 | 117 |
| 9.1.3 | Multi-antenna & sub-array control | 0 | 6 | 0 | 0 | 36 | 100 | 34% | 182 | 222 |
| 9.1.4 | Operators and Observers Interfaces | 0 | 0 | 0 | 0 | 0 | 20 | 34% | 27 | 33 |
| 9.1.5 | Deliver control software | 0 | 0 | 0 | 0 | 0 | 0 | 30% | 0 | 0 |
| 9.1.6 | Maintenance | 0 | 0 | 0 | 0 | 0 | 0 | 18% | 0 | 0 |
| 9.2 | Scheduling | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.2.1 | Static Scheduling System | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 9.2.2 | Dynamic scheduling simulations | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 9.2.3 | Dynamic scheduling prototype | 0 | 0 | 0 | 0 | 0 | 0 | 30% | 0 | 0 |
| 9.2.4 | Dynamic scheduling implementation | 6 | 12 | 0 | 0 | 114 | 0 | 39% | 159 | 194 |
| 9.3 | Proposal preparation software | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.3.1 | Proposal assistance prototype | 0 | 0 | 0 | 0 | 0 | 0 | 30% | 0 | 0 |
| 9.3.2 | Proposal assistance implementation | 3 | 6 | 0 | 0 | 57 | 0 | 30% | 74 | 91 |
| 9.3.3 | Observe program prototype | 0 | 0 | 0 | 0 | 0 | 0 | 26% | 0 | 0 |
| 9.3.4 | Observe program | 3 | 0 | 0 | 0 | 21 | 0 | 26% | 27 | 33 |
| 9.4 | Image pipeline | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.4.1 | Automated calibration & imaging heuristics | 0 | 0 | 0 | 0 | 0 | 0 | 39% | 0 | 0 |
| 9.4.2 | Prototype image pipeline | 0 | 0 | 0 | 0 | 0 | 0 | 30% | 0 | 0 |
| 9.4.3 | Parallelization studies and implementation | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 9.4.4 | Initial image pipeline operations | 0 | 0 | 0 | 0 | 0 | 0 | 26% | 0 | 0 |
| 9.4.5 | Production image pipeline | 6 | 12 | 0 | 0 | 114 | 250 | 30% | 474 | 577 |
| 9.5 | Archiving | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.5.1 | Prototype distributed archive | 0 | 0 | 0 | 0 | 0 | 0 | 30% | 0 | 0 |
| 9.5.2 | Evaluate storage hardware | 0 | 0 | 0 | 0 | 0 | 0 | 11% | 0 | 0 |
| 9.5.3 | Production archive | 3 | 12 | 0 | 0 | 93 | 268 | 30% | 469 | 572 |
| 9.6 | Post processing | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.6.1 | Define data formats | 0 | 0 | 0 | 0 | 0 | 0 | 18% | 0 | 0 |
| 9.6.2 | Filler and format conversions | 0 | 0 | 0 | 0 | 0 | 0 | 22% | 0 | 0 |
| 9.6.3 | ALMA specific calibrations | 0 | 0 | 0 | 0 | 0 | 0 | 39% | 0 | 0 |
| 9.6.4 | MMA Post-processing begins | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.6.5 | Maintenance | 0 | 0 | 0 | 0 | 0 | 0 | 22% | 0 | 0 |
| 9.7 | Software support | 0 | 0 | 0 | 0 | 0 | 0 | 0% | 0 | 0 |
| 9.7.1 | Tool support | 0 | 0 | 0 | 0 | 0 | 0 | 34% | 0 | 0 |
| 9.7.2 | Quality assurance | 0 | 18 | 0 | 0 | 107 | 0 | 34% | 144 | 175 |
| 9.7.3 | Chile system administration | 0 | 0 | 0 | 0 | 0 | 0 | 22% | 0 | 0 |
| | | | | | | | | | | |
| 10 | System Integration | 0 | 0 | 0 | 0 | 0 | 0 | 10% | 0 | 0 |
| 10.4 | Test Interferometer Site Preparation | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.10 | Oufitting at U.S. test site | 0 | 0 | 0 | 0 | 0 | 0 | 12% | 0 | 0 |
| 10.10.4 | Antenna #1 Outfitting | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.10.7 | Antenna #2 Outfitting | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.10.10 | General Outfitting | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.11 | Single Dish Tests | 0 | 0 | 0 | 0 | 0 | 0 | 11% | 0 | 0 |
| 10.11.1 | Ant #1 holography and surface readjustment | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.11.2 | Ant #1 Antenna Evaluation | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.11.6 | Ant #2 holography and surface readjustment | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |

# Millimeter Array Construction: 2007

US Reference Project

| WBS | Task Name | Scientists Work-months | Programmers Work-months | Engineers Work-months | Technicians Work-months | Personnel 1999 $K | Materials & Supplies 1999 $K | Contingency | Total Cost 1999 $K | Inflated Cost 2007 $K |
|---|---|---|---|---|---|---|---|---|---|---|
| 10.11.7 | Ant #2 Antenna Evaluation | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.12 | Interferometric Tests | 0 | 0 | 0 | 0 | 0 | 0 | 11% | 0 | 0 |
| 10.12.1 | Phase/gain stability tests | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.12.2 | Sensitivity verification | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.12.3 | Holography with astronomical sources | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.12.4 | Modifications and Retrofits | 0 | 0 | 0 | 0 | 0 | 0 | 35% | 0 | 0 |
| 10.13 | Dissassemble test system and ship to array site | 0 | 0 | 0 | 0 | 0 | 0 | 35% | 0 | 0 |
| 10.14 | On-site System Integration | 0 | 0 | 0 | 0 | 0 | 0 | 50% | 0 | 0 |
| 10.14.1 | Set up assembly and test facilities at OSF | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.14.2 | Outfit antennas 3 through 36 | 0 | 0 | 0 | 0 | 0 | 10 | 25% | 13 | 15 |
| 10.14.2.1 | Wiring and plumbing | 0 | 0 | 0 | 6 | 22 | 66 | 25% | 110 | 134 |
| 10.14.2.2 | Install electronics in receiver cabin | 0 | 0 | 0 | 6 | 22 | 66 | 25% | 110 | 134 |
| 10.14.2.3 | Check out completed antenna at OSF | 1 | 0 | 6 | 6 | 71 | 0 | 25% | 89 | 109 |
| 10.14.2.4 | Install antenna at array site. | 0 | 0 | 0 | 6 | 25 | 0 | 25% | 31 | 37 |
| 10.14.3 | Refurbish antennas 1 and 2 | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.14.3.1 | Re-install electronics and upgrade as needed | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.14.3.2 | Check out at OSF | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.14.3.3 | Install antenna at array site | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.14.4 | Install central building electronics | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.14.5 | Support debugging and repair | 0 | 0 | 0 | 0 | 0 | 0 | 25% | 0 | 0 |
| 10.20 | Prototype Testing Support | 0 | 0 | 0 | 0 | 0 | 0 | 10% | 0 | 0 |
| | | | | | | | | | | |
| 11.1.1 | Completion of 183 GHz Water Vapor Radiometer | 0 | 0 | 0 | 0 | 0 | 0 | 11% | 0 | 0 |
| 11.1.2 | Demonstrate 183 GHz Water Vapor Radiometer | 0 | 0 | 0 | 0 | 0 | 0 | 12% | 0 | 0 |
| 11.1.3 | Refinement of 183 GHz Water Vapor Radiometer | 0 | 0 | 0 | 0 | 0 | 0 | 16% | 0 | 0 |
| 11.1.4 | Release WVR for manufacture | 0 | 0 | 0 | 0 | 0 | 0 | 10% | 0 | 0 |
| 11.2.1.1 | Contract Phase Monitor Radiometer Subassembly | 0 | 0 | 0 | 0 | 0 | 0 | 10% | 0 | 0 |
| 11.2.1.2 | WVR Spectrometer | 0 | 0 | 0 | 0 | 0 | 0 | 10% | 0 | 0 |
| 11.2.1.3 | WVR Feed, Window, Lens, Instrumentation | 0 | 0 | 0 | 0 | 0 | 0 | 10% | 0 | 0 |
| 11.2.1.4 | Monitor and Control WVR Interface | 0 | 0 | 0 | 0 | 0 | 0 | 14% | 0 | 0 |
| 11.2.3 | Deliver Production Radiometers | 0 | 0 | 0 | 0 | 0 | 0 | 9% | 0 | 0 |
| 11.2.4 | Integration of WVR into Receiver Package | 0 | 0 | 0 | 0 | 0 | 0 | 7% | 0 | 0 |
| 11.2.5 | Verification on Site of WVR | 0 | 0 | 0 | 0 | 0 | 0 | 9% | 0 | 0 |
| 11.3.1 | Dual-Load Amp. Calibration Device Design Refinement | 0 | 0 | 0 | 0 | 0 | 0 | 7% | 0 | 0 |
| 11.3.2 | Release Dual-Load Amp Cal for Mftr | 0 | 0 | 0 | 0 | 0 | 0 | 8% | 0 | 0 |
| 11.3.3 | Contract Subassembly Dual-Load Amp Cal | 0 | 0 | 0 | 0 | 0 | 0 | 7% | 0 | 0 |
| 11.3.3.1 | Dual-Load AmpCal Subassy Machining | 0 | 0 | 0 | 0 | 0 | 0 | 7% | 0 | 0 |
| 11.3.3.2 | Load Fabrication for Dual Load Amp Cal | 0 | 0 | 0 | 0 | 0 | 0 | 7% | 0 | 0 |
| 11.3.3.3 | Dual Load Amplitude Calibration Device Motors, Servo | 0 | 0 | 0 | 0 | 0 | 0 | 7% | 0 | 0 |
| 11.3.3.4 | M/C Interface for Dual Load Amp Cal Device | 0 | 0 | 0 | 0 | 0 | 0 | 7% | 0 | 0 |
| 11.3.4 | Assembly and Test of Dual Load Amplitude Calibration | 0 | 0 | 0 | 0 | 0 | 0 | 7% | 0 | 0 |
| 11.3.5 | Integration of AmpCal on Production Antennas | 0 | 0 | 0 | 3 | 12 | 0 | 7% | 13 | 15 |
| 11.4 | Imaging Studies and Project Support | 0 | 0 | 0 | 0 | 0 | 0 | 5% | 0 | 0 |
| 11.5 | Imaging Algorithm Development | 0 | 0 | 0 | 0 | 0 | 0 | 7% | 0 | 0 |
| | | | | | | | | | | |
| | Totals | 82 | 78 | 172 | 376 | 3,769 | 28,860 | | 40,971 | 49,920 |