

FINAL 04/05

AGREEMENT

CONCERNING THE JOINT CONSTRUCTION AND OPERATION OF THE ATACAMA LARGE MILLIMETER ARRAY

(ALMA)

BY

The National Science Foundation of the United States

hereinafter referred to as "NSF",

and

The European Organisation for Astronomical Research in the Southern Hemisphere,

hereinafter referred to as "ESO" or "The European Southern Observatory"

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PREAMBLE

NSF and ESO (hereinafter referred to as the 'Parties'), desiring to

- contribute to global advances in understanding the physics of the Universe;
- ensure a continuing active program of astronomical research in Europe and the United States and Canada;
- encourage further scientific collaboration between the Parties, and other organizations with an interest in millimeter astronomy; and
- achieve full intellectual and economic benefits to all organizations and institutes participating in ALMA, with a fair and equitable division of responsibilities and benefits among them, consistent with their contributions and the cost-effective and timely execution of this project;

and recognizing

- the potential of large interferometric arrays operating at millimeter and submillimeter wavelengths to contribute to the study of a wide range of astronomical problems;
- the interest of the astronomical communities of Europe, the United States and Canada in developing such an array;
- the interest of other astronomical communities in participating in a large millimeter and submillimeter interferometric array project;
- the advantages of combining these aspirations in a single global project;
- the necessity to locate such an instrument at a dry, high altitude site;
- the identification of a suitable site in a region of the Altiplano in northern Chile known as Zona Chajnantor–Cerro Chascon; and
- that, by virtue of a Memorandum of Understanding (MoU) dated 10 June 1999, as amended, between NSF, the National Research Council of Canada (NRC), and ESO, with the Centre National de la Recherche Scientifique (CNRS) of France, the Max-Planck-Gesellschaft (MPG) of Germany, the Netherlands Foundation for Research in Astronomy/Nederlandse Onderzoekschool voor Astronomie (NFRA/NOVA), the Particle Physics and Astronomy Research Council (PPARC) of the United Kingdom, the Swedish Natural Science Research Council (NFR), and the Oficina de Ciencia y Tecnología and the Instituto Geográfico of Spain (OCYT/IGN), an extensive joint Design and Development program has been carried out in preparation for the construction and operation of the Atacama Large Millimeter Array project,

agree as follows:

ARTICLE 1: DEFINITIONS

"This Agreement" means the following Articles and Annexes.

"Assessment Point" means the time(s) at which the Parties must decide whether or not to continue their collaboration.

"ALMA" means the collaborative project involving the joint Construction, Commissioning, and Operation of the Atacama Large Millimeter Array by the Parties.

"Board" means the Board established under Article 12.

"Budget" means an estimate of income, commitment and expenditure on ALMA within a specified Financial Year.

"Commissioning" means those activities by which the antennas and instrument systems are integrated and tested with instrumentation then available and brought into proper operation.

"Construction" means the planning, design, construction, and installation of antennas, infrastructure, and instrumentation.

"Deliverables" means the components of ALMA which have been assigned Value as set out in Annex D of this Agreement.

"Early Operations" refers to the scientific use of ALMA prior to the installation of the full complement of antennas and their associated instrumentation.

"Engineering" means the activities necessary for both the maintenance and improvement of ALMA and its instrumentation.

"Executives" means the entities designated under Article 13 of this Agreement to carry out the specific tasks required to construct and operate ALMA.

"Financial Year" means the 12-month period beginning January 1 and ending December 31.

"Intellectual Property" means intellectual and industrial property produced or generated during the performance of the Work which is capable of protection by patents, trademarks or copyright, and industrial design, technical information, inventions, prototypes and specifications produced or generated in the performance of the Work, which are capable of being licensed.

"Joint ALMA Office" means the entity established and described in Article 14 to be responsible for the overall management of ALMA Construction, Commissioning and Operations.

"Key Personnel" are the individuals in the positions described in Article 15, who play a central role in the Construction, Commissioning and Operation of ALMA.

"Long Range Plan" means the document submitted annually by the Director to the Board that summarizes future plans and financial projections for ALMA. The Long Range Plan will summarize the current project scope, scientific requirements, Work Breakdown Structure, and schedule, as well as the management and operations plans. During Construction the Long Range Plan shall cover the entire Construction period. During Early Operations and Operations, the

period covered by the Long Range Plan shall become five years, or to the end of the Construction period, whichever is the greater.

“Observing Time” means the time scheduled for the observing of astronomical objects for scientific purposes, excluding the time required for Engineering and Commissioning.

“Operations” means the stage after all ALMA antennas and their associated instrumentation as specified in Annex A have been fully commissioned, tested and accepted, and are operational.

“Party” means any signatory to this Agreement.

“Program Plan” means the document submitted annually by the Director to the Board that summarizes the Work to be conducted by the Executives in the upcoming Financial Year.

“Value” means the agreed worth of a Deliverable, expressed according to the model agreed upon by the Parties under the provisions of Article 5 of this Agreement, and as set forth in Annex D.

“Work” means any activity approved by the Board relating to ALMA according to the Project Description attached as Annex A, and the Work Breakdown Structure attached as Annex D.

ARTICLE 2: CONTRIBUTIONS

- 2.1 NSF and ESO will each make equal Value contributions to ALMA. To the maximum extent practicable, Work shall be fairly and equitably shared between NSF's designated Executive and ESO.
- 2.2 The Parties, including their organizations and institutes, shall obtain intellectual and economic benefit from ALMA in all its phases in proportion to the Value of their contributions and consistent with the execution of assigned tasks on time and within budget.
- 2.3 Wherever practicable, ALMA will utilize existing institutions. Where necessary, personnel will be supplied by secondment from existing institutions. To the maximum extent possible, there shall be no exchange of funds between the Parties.

ARTICLE 3: OBJECTIVE

- 3.1 The objective of the Parties is to jointly carry out ALMA as a bilateral project between NSF and ESO in accordance with this Agreement and the Project Description; Science Requirements; Project Time Schedule; Work Breakdown Structure, Assignment of Deliverables, and Schedule of Values, as specified in Annexes A, B, C, and D, respectively.
- 3.2 NSF shall carry out its obligations under this Agreement subject to its applicable national laws and regulations, and ESO shall carry out its obligations under this Agreement within the framework of its Convention and statutes.

ARTICLE 4: SCOPE

- 4.1 This Agreement covers Construction, Commissioning, Early Operations, and Operations.

ARTICLE 5: VALUATION

- 5.1 The Parties shall use a single, mutually accepted costing model, as described in Annex D, to determine the Value of their contributions to ALMA. The Schedule of Values and Assignment of Deliverables for Construction are specified in Annex D.
- 5.2 Schedules of Values for Early Operations and Operations shall be determined by the Board prior to the start of those phases of the project and shall be incorporated in Annex D.
- 5.3 The components provided to ALMA shall be subject to common specifications and acceptance criteria. Defining, maintaining, and implementing ALMA specifications and acceptance criteria shall be the responsibility of the Joint ALMA Office.

ARTICLE 6: AMENDMENT

- 6.1 The Articles to this Agreement may be amended at any time. An amendment must specifically state the intention to amend this Agreement, and takes effect when signed and dated by the Parties.
- 6.2 The Annexes to this Agreement may be amended by the unanimous approval of the Board provided such amendment does not significantly alter the purpose of this Agreement and is consistent with the costing model agreed to by the Parties.

ARTICLE 7: DURATION AND TERMINATION

- 7.1 This Agreement shall enter into force on the date on which the last Party signs and shall expire on December 31, 2021 unless extended under Articles 7.2 and 7.3.
- 7.2 At pre-agreed Assessment Points, the Parties shall decide whether to extend this Agreement for a further period, normally of at least 5 years. In the absence of such a decision, this Agreement shall terminate on the last expiration date set.
- 7.3 The first Assessment Point shall be January 5, 2018. Subsequent Assessment Points shall be on the 5th of January at succeeding 5-year intervals unless otherwise agreed to in writing by the Parties.
- 7.4 In the event that this Agreement is terminated during Construction, Commissioning, or Operations, property shall revert to the owners as defined in Article 10.1 of this Agreement. Any additional costs or benefits shall be shared by the Parties in proportion

to the Value of their contributions to ALMA up to the time at which this Agreement is terminated.

- 7.5 Before this Agreement is terminated, the Parties shall make best efforts to agree on the date and the manner in which the assets and obligations of ALMA shall be disposed of. Unless otherwise agreed, the owners of property shall be responsible for the disposal of that property. The costs or benefits arising from the disposal of jointly owned assets, including the net proceeds that may arise from the sale of such assets, shall be divided between the Parties in proportion to their contributions to those assets.

ARTICLE 8: WITHDRAWAL

- 8.1 A Party wishing to withdraw from this Agreement shall provide written notice to the other Party. If a Party gives notice of withdrawal from this Agreement, the Parties, with a view toward ensuring the continuation of the overall program, shall endeavor to reach agreement concerning the terms and conditions of the withdrawal prior to the effective date of the withdrawal.
- 8.2 The extent to which Work already completed and delivered and, where relevant, funds already paid, entitle a withdrawing Party to Observing Time after withdrawal shall be determined by the Parties prior to the effective date of the withdrawal. A withdrawing Party may not transfer any rights to Observing Time without the prior agreement of the other Party.
- 8.3 The withdrawing Party shall, at the request of the other Party, transfer, to the extent necessary for the continuation of ALMA, its right, title, and interest in any property, contracts (to the extent allowed under those contracts) or work in progress funded out of money contributed to ALMA under this Agreement to such other persons or bodies as the other Party directs and shall otherwise cooperate in order to facilitate the continuation of ALMA by the other Party.
- 8.4 The withdrawing Party shall not transfer any right, title, or interest in any property, contracts (to the extent allowed under those contracts) or work in progress funded out of money contributed to ALMA under this Agreement without the prior agreement of the other Party.
- 8.5 Notwithstanding Articles 8.2 and 8.3, a withdrawing Party shall retain its rights in Intellectual Property acquired as at the effective date of withdrawal.
- 8.6 Except as provided in Articles 8.2, 8.3, and 8.4 of this Agreement or as otherwise agreed by the Parties, all rights and benefits conferred on a Party under this Agreement shall be forfeited at the effective date of withdrawal.

ARTICLE 9: PRECEDENCE

- 9.1 This Agreement shall take precedence over all prior communications, negotiations and agreements between the Parties concerning ALMA.
- 9.2 The Articles of this Agreement shall take precedence over the Annexes.
- 9.3 Neither Party shall enter into agreements concerning ALMA with third parties that conflict with the terms of this Agreement.

ARTICLE 10: OWNERSHIP

- 10.1 Deliverables supplied by NSF shall be the property of the Government of the United States. Deliverables supplied by ESO shall be the property of ESO. Intellectual property shall be subject to the provisions of Articles 8.6 and 23 of this Agreement. Material property delivered to, or developed for, ALMA shall not be disposed of, in whole or in part, during the duration of this Agreement without the written consent of all the Parties, except as allowed for in Articles 10.3 and 10.4 of this Agreement.
- 10.2 The Parties acknowledge that exports from the United States and Europe will be subject to the requirements of applicable export regulations. Such controlled exports may involve either material or intellectual property transferred from the United States or Europe to foreign countries, foreign entities or foreign nationals for the purpose of Construction, Commissioning, Early Operations, or Operations.
- 10.3 The Executives may dispose of equipment, the value of which does not exceed a limit set from time to time by the Board, subject to the said equipment being either surplus to the future requirements of ALMA or unserviceable and beyond economical repair. Initially, that limit shall be 0.1% of the total Value of ALMA as defined in Annex D. Surplus equipment shall be offered for sale to the Parties before being offered for sale elsewhere. The Executives shall use their best efforts to ensure that all proceeds realized from such sales shall be reinvested in ALMA in a manner approved by the Board.
- 10.4 Where the value of equipment identified for disposal exceeds the limit referred to in Article 10.3 of this Agreement, the Executives shall seek the approval of the Board before disposing of the equipment.
- 10.5 The Executives shall maintain a system tracking the ownership, location and, if applicable, the disposition of delivered equipment.

ARTICLE 11: NEW PARTICIPANTS IN ALMA

- 11.1 The Parties shall agree upon the terms and conditions through which organizations not covered by this Agreement may participate in ALMA, and shall conclude appropriate formal arrangements with such organizations before they can benefit from participation.

ARTICLE 12: BOARD

- 12.1 A Board shall be established by the Parties as a supervisory and regulatory body for ALMA, and to be the primary forum for interactions among, and decisions of, the Parties to this Agreement.
- 12.2 All decisions of the Board shall be consistent with this Agreement and with the governing laws, regulations and contractual obligations of the Parties and the Executives.
- 12.3 The Board shall not be a legal entity and shall not employ staff or hold assets.
- 12.4 The Board shall ensure that Construction, Commissioning, Early Operations, and Operations are carried out jointly in accordance with the terms and provisions of this Agreement. The Board shall exercise budgetary oversight and policy control over ALMA in accordance with the provisions of this Agreement.
- 12.5 The Board shall, *inter alia*,
- (a) report at least once per year in writing to the Parties to this Agreement on the status of ALMA, including the financial situation, progress on Construction and Commissioning, and projected timescales, estimated cost to completion, and the status of Early Operations and Operations;
 - (b) determine the dates of completion of Construction and of Commissioning, the date of the start of Early Operations, and any reapportionment of Value between Construction and Commissioning and Early Operations where those periods may overlap;
 - (c) determine the policy and manner in which Early Operations and Operations will be carried out;
 - (d) determine the policy and procedures for the allocation of Observing Time;
 - (e) determine the policy and procedures for data rights and the proprietary period;
 - (f) approve a Budget and Program Plan for the following year and endorse a Long Range Plan; and
 - (g) undertake such other duties and responsibilities to facilitate implementation this Agreement.
- 12.6 NSF and ESO shall each appoint four members to the Board. One member appointed by NSF shall represent the U.S. Executive, and one ESO Board member shall represent the European Executive. ESO shall designate one of its appointees to speak on behalf of ESO and NSF shall designate one of its appointees to speak on behalf of NSF on matters before the Board.
- 12.7 The Board shall meet not less than two times per year.

- 12.8 Such other persons may be invited to attend meetings of the Board as the Board from time to time determines.
- 12.9 The Board shall designate one of its members as a Chairperson. The Chairperson shall rotate every 2 years between a Board member appointed by NSF and a Board member appointed by ESO, with the member designated by ESO serving as Chairperson from the date upon which this Agreement shall enter into force. In the event that a Board member cannot complete a full 2-year term as Chairperson, a successor appointed by the Party that appointed the outgoing Chairperson, shall be designated for the remainder of the outgoing Chairperson's term.
- 12.10 The Board shall designate one of its members as Vice Chairperson. The Vice Chairperson shall rotate every 2 years between a Board member appointed by ESO and a Board member appointed by NSF, with the member designated by NSF serving as Vice Chairperson from the date upon which this Agreement shall enter into force. In the event that a Board member cannot complete a full 2-year term as Vice Chairperson, a successor appointed by the Party that appointed the outgoing Vice Chairperson, shall be designated for the remainder of the outgoing Vice Chairperson's term.
- 12.11 Neither the Chairperson nor the Vice Chairperson may be an employee of either Executive.
- 12.12 A Secretary to the Board shall be employed by the Executives to be responsible for the support of the Board including keeping records of the meetings and decisions of the Board.
- 12.13 The Parties shall advise the Secretary, in writing, of the members they have appointed to the Board and of the duration of the appointments. The Secretary shall be responsible for notifying the Chairperson, Board members, and the Parties.
- 12.14 The Parties may change their appointed members by notifying in writing the Secretary, who shall be responsible for notifying the Chairperson, Board members, and the Parties.
- 12.15 The Parties may appoint alternate members to attend and vote at specific Board meetings in place of regular members, by notifying in writing the Secretary, who shall be responsible for notifying the Chairperson, Board members, and the Parties. Alternates may not serve as either Chairperson or Vice Chairperson.
- 12.16 The Board may adopt common oversight and management activities chargeable to ALMA, and may request the Executives to arrange for the employment of staff to assist in such tasks. Expenses related to such oversight functions as may be required by an individual Party to this Agreement shall be the responsibility of that Party. Expenses for oversight and management activities undertaken at the request of the Board shall be equitably shared by the Parties.
- 12.17 The Rules of Procedure of the Board shall be drawn up by the Secretary and shall be subject to the unanimous agreement of the Board.
- 12.18 English shall be the working language of the Board and of ALMA.

- 12.19 The Parties are responsible for their own expenses incurred in pursuit of Board business by their appointees to the Board.

ARTICLE 13: EXECUTIVES

- 13.1 Two Executives shall carry out jointly the Construction, Commissioning, Early Operations, and Operations of ALMA on behalf of their respective Parties. The European Executive shall be ESO and the NSF Executive shall be Associated Universities Inc. (AUI), in its capacity as manager of the National Radio Astronomy Observatory (NRAO). NSF and ESO may change their Executives, and will notify the Board in writing of such changes.
- 13.2 Funding and Deliverables for ALMA shall be provided by the Parties through the Executives.
- 13.3 The Executives shall, *inter alia*:
- (a) receive, track, and maintain records of contributions from the Parties;
 - (b) forward such records with appropriate evaluations to the Joint ALMA Office to enable it to fulfill all reporting requirements to the Board;
 - (c) ensure that all contributions for ALMA can be examined by the Parties upon reasonable request;
 - (d) carry out the decisions of the Board and the Director;
 - (e) employ the Key Personnel and staff to carry out Work and related activities, and to issue contracts for goods and services;
 - (f) ensure that at all reasonable times representatives of the Parties have access to all Work and associated documents related to ALMA on the premises of the Executives, and to all Work at the Joint ALMA Office and its subsidiaries and at all ALMA sites within Chile; and
 - (g) report regularly to the Board as required by this Agreement, and at other times when in the judgment of the Executives such reporting is warranted.
- 13.4 When leadership and responsibility for a task are assigned to a particular Executive, they shall be exercised in cooperation with the other Executive.

ARTICLE 14: JOINT ALMA OFFICE

- 14.1 The Board shall establish a Joint ALMA Office and shall provide through the Executives the necessary funding, infrastructure and personnel support to operate the Joint ALMA Office through the Executives.

- 14.2 The Joint ALMA Office shall be headed by the Director and shall be comprised of the Key Personnel plus such other staff as are required to carry out the functions of the Joint ALMA Office. The Executives shall employ, or arrange for the employment of the staff of the Joint ALMA Office, including the Key Personnel.
- 14.3 The Joint ALMA Office shall *inter alia*, through the Director,
- (a) be responsible for the overall leadership and management of joint Construction, Commissioning, Early Operations, and Operations, which shall be carried out in accordance with the terms and provisions of this Agreement;
 - (b) define, maintain, and apply specifications and acceptance criteria for Deliverables. In the event that Deliverables fail to meet acceptance criteria, the Joint ALMA Office shall notify the responsible Party and the Board, and shall devise a recovery plan for the approval of the Board.
 - (c) propose to the Board by September 30 of each year a draft Budget and Program Plan for the following year and a long range plan, including long-range financial estimates encompassing anticipated project needs for a period no less than 5 years in the future; and
 - (d) provide for the Board quarterly reports of the status of ALMA.

ARTICLE 15: KEY PERSONNEL

- 15.1 The organizational structure of ALMA shall be subject to the review and approval of the Board, and Key Personnel shall be designated from time to time by the Board. Initially, the Key Personnel shall include:
- (a) The **Director**: responsible for leading ALMA. He/she reports to the Board.
 - (b) The **Project Manager**: responsible for the overall coordination of Construction and Commissioning. He/she reports to the Director.
 - (c) The **Project Scientist**: responsible for ensuring that ALMA Construction, Commissioning and Operations are carried out in such a manner as to meet the scientific requirements of Annex B. He/she reports to the Director.
 - (d) The **Project Engineer**: responsible for ensuring that the technical specifications of ALMA are fulfilled and that the instrument is maintained in such a way as to ensure its full operational capabilities. He/she reports to the Director.
- 15.2 Key Personnel shall be selected through an open, world-wide search carried out jointly by the Executives in a manner approved by the Board. The job descriptions and appointment of all Key Personnel shall be subject to the unanimous approval of the Board.
- 15.3 The Director shall be responsible for the efficient and effective operation, and for the discharge of the responsibilities of, the Joint ALMA Office. The Director shall be

responsible for the Project Time Schedule and Work Breakdown Structure, and for the maintenance of the Schedule of Values and Assignment of Deliverables as set out in Annexes C and D.

- 15.4 In consultation with the Executives, and with Board approval if the Value concerned exceeds \$1 million or €1 million, the Director may change the Project Time Schedule and Work Breakdown Structure, and the Schedule of Values and Assignment of Deliverables while maintaining parity of Value in the contributions of the Parties. The Director's approval shall be required for such staff appointments as shall be defined by the Director in consultation with the Executives, and for the placing of any contracts above \$500,000 or €500,000. The approval of the Director, and Board approval if the total amount concerned exceeds \$1 million or €1 million, shall be required for the use of contingency in excess of \$500,000 or €500,000 by the Executives.
- 15.5 The Director shall allocate Observing Time during Early Operations and Operations in accordance with policies and procedures determined by the Board.
- 15.6 The job performance of all Key Personnel shall be reviewed annually by the Board in consultation with the Director and the Executives. Board approval will be required for the continued appointment of all Key Personnel.

ARTICLE 16: ALMA MANAGEMENT ADVISORY COMMITTEE

- 16.1 The Board shall establish an ALMA Management Advisory Committee (AMAC) to provide advice on those major issues presented to the AMAC by the Board regarding the technical program, cost, and management of the ALMA Project, including the management of specific tasks and resources. The Parties shall each appoint up to five members to the AMAC; such appointments require the concurrence of the Board. Members shall serve for a term of 3 years, but may be reappointed for a second term.
- 16.2 The AMAC shall be kept informed of progress and developments in ALMA through periodic reports and briefings provided by the Joint ALMA Office, and will normally meet at least twice a year. Reports of the AMAC's deliberations shall be made in writing to the Board by the Chairperson of the AMAC following each Committee meeting, on a schedule specified in advance by the Board.
- 16.3 At each meeting, the AMAC shall select a Chairperson for its next meeting. At successive meetings, the Chairperson shall alternate between a representative appointed by ESO and a representative appointed by NSF. The selection of the Chairperson shall be subject to the concurrence of the Board.

ARTICLE 17: ALMA SCIENCE ADVISORY COMMITTEE

- 17.1 The Board shall establish an ALMA Science Advisory Committee (ASAC) to advise the Board on those major issues presented to the ASAC by the Project Scientist or the Board that affect the science capabilities of ALMA and require decisions to be made or

priorities to be set regarding project tasks and resources. ESO shall appoint up to five ASAC members and NSF shall appoint up to five ASAC members; such appointments require the concurrence of the Board. Each member shall serve a term of 3 years. Members may be reappointed for a second term.

- 17.2 The ASAC shall be kept informed of progress and developments in ALMA through periodic reports and briefings provided by the Joint ALMA Office and shall meet at least twice a year. Reports of the ASAC's deliberations shall be made in writing to the Board by the Chairperson of the ASAC following each Committee meeting, on a schedule specified in advance by the Project Scientist. The Project Scientist shall serve on the Committee *ex officio*.
- 17.3 The Chairperson of the ASAC shall be selected by the members of the ASAC, and the selection shall be subject to the concurrence of the Board. At successive meetings, the Chair shall alternate between an ASAC member selected by NSF and an ASAC member selected by Europe.

ARTICLE 18: CHILE

- 18.1 AUI and ESO shall jointly negotiate the terms and conditions under which the Government of Chile grants access to the land required for ALMA and permits Construction, Commissioning and Operation. AUI and ESO shall jointly negotiate with the Government of Chile the fraction of Observing Time made available to the Chilean astronomical community.

ARTICLE 19: FINANCIAL PROVISIONS - GENERAL

- 19.1 The Parties intend that the funds that they will set aside and obligate from time-to-time to ALMA will meet their obligations under this Agreement. However, it is recognized that the Parties must operate within the constraints of the funding made available by national governments and funding agencies. Therefore, the obligations under this Agreement are subject to the availability of appropriated funds.
- 19.2 Financial matters before the Board as set out in this Article shall require the agreement of six Board members, including both the ESO and NSF designated members of the Board.

Accounting and Audits

- 19.3 Where cash accounting is required, records shall be kept of costs in both US dollars and Euros. Costs in these currencies shall be determined using the exchange rates obtaining at the time of the expenditures.
- 19.4 The Financial Year of ALMA shall be the calendar year (January 1 through December 31).

- 19.5 On or before November 30 each year, the Board shall approve a Budget and Program Plan for the following year and endorse a Long Range Plan.
- 19.6 Within two months of the end of each Financial Year, the Executives shall provide the Joint ALMA Office with reports for monies spent and/or Value earned during that Financial Year. The Joint ALMA Office shall in turn provide to the Board a final summary report for the Financial Year in question no later than three months after the conclusion of the Financial Year. The Executives shall certify the accuracy of their annual reports.
- 19.7 For each Financial Year the amount and timing of the contributions to ALMA from NSF and ESO shall be agreed at the Board meeting that considers the Budget.
- 19.8 Funds provided to the Executives for ALMA shall be subject to an annual external review, the results of which shall be made available to the Parties via the Board.
- 19.9 NSF and ESO shall arrange for an external review of their respective Executive activities at intervals of not less than three years, and shall make the results of these reviews available to the Parties through the Board.

ALMA Board expenses

- 19.10 A Party hosting a meeting of the Board shall be responsible for the local costs of arranging the meeting.

Contracts

- 19.11 The Executives shall, to the maximum extent practicable, make sub awards on the basis of competitive international tender in a manner which shall enable competitive bidding by companies within the respective Parties' countries on terms which are not selectively to the disadvantage of the companies of any of those countries. Such awards shall be subject to external audit, the results of which shall be reported to the Board.
- 19.12 The Executives shall notify the Board in advance through the Director of the intention to place any contract valued above \$1,000,000 or €1,000,000. The Executives shall notify the Board in advance through the Director of the intention to issue an invitation to tender for a contract provisionally valued above \$10,000,000 or €10,000,000. The placing of any contract above \$10,000,000 or above €10,000,000 shall require the recommendation of the Director and the concurrence of the Board.

Observing

- 19.13 Funding of the travel and subsistence costs of observers or others wishing to use ALMA is outside the scope of this Agreement.

ARTICLE 20: DEFAULT

- 20.1 An Executive which expects to default on an obligation for a Deliverable, either through late delivery, failure to meet specification, or any other cause, shall immediately inform

the Director and the Board through the Secretary in writing, together with an explanation of the causes and proposed actions to be taken. The Director shall provide the Board through the Secretary with an evaluation of the likely consequences of such default, and advise the Board of the actions the Director intends to take to minimize the impact on ALMA. The Secretary shall also pass this information to the Executives and the Parties. In consultation with the Parties, the Chairperson shall decide whether Board approval for such actions is required, and how such approval should be obtained.

- 20.2 The Director may recommend to the Chairperson that the Board establish a mechanism to revise the Value of the Deliverable, and may propose any compensatory action, including cash payments and a readjustment of Observing Time, taking into account the proposed remedial action and its impact on the Executives, the Parties and on ALMA, so that the Board may take such steps as are necessary to ensure that the terms of Article 2 of this Agreement are maintained.
- 20.3 The Director shall immediately implement such steps as shall be agreed by the Board.
- 20.4 An Executive which is in default for more than 360 calendar days during Operations shall be considered as having signaled the intent of the corresponding Party to withdraw from ALMA and the relevant provisions of Article 8 of this Agreement shall apply.

ARTICLE 21: OBSERVING TIME AND DATA RIGHTS

- 21.1 The Director may propose incentives for enhanced performance by the Executives to the Board for approval. The award of Observing Time during Early Operations may be used as such an incentive.
- 21.2 The Observing Time available to the Parties during Operations shall be divided between them in equal shares, and distributed equitably according to the seasons of the year.
- 21.3 The Executives shall arrange for the maintenance of a log and an archive copy of each observation and its relevant calibration data in a single, uniform data format accessible to qualified researchers as approved by the Board. For this purpose, the Executives may choose to employ mirrored data sites for the convenience of their respective user communities.
- 21.4 The Board shall set policies for proprietary time, data storage, archiving, access, and subsequent use by the astronomical community. The rules relating to Observing Time and data rights shall be reviewed periodically by the Board.
- 21.5 Any observer who takes data with ALMA shall have exclusive use of that data for 18 months after the collection of the data has been completed. Thereafter, the data shall become available to any qualified researcher in accord with a policy approved by the Board.

ARTICLE 22: ACCESS TO OBSERVING TIME BY OTHERS

- 22.1 Either Party may, with the written agreement of the other, assign its Observing Time, in whole or in part, for a fixed period of time, to another entity not a Party to this Agreement. Agreement to such assignments, which must be in accordance with this Agreement, shall not be unreasonably withheld, delayed or denied.
- 22.2 Third parties receiving the assignment of Observing Time under Article 22.1 of this Agreement shall be expected to abide by all rules pertaining to ALMA Operations and data release.

ARTICLE 23: INTELLECTUAL PROPERTY

- 23.1 Except as provided in Articles 21.3 through 21.5 of this Agreement concerning data acquired with ALMA, the inventor or creator of Intellectual Property or his or her assignee or employer shall own or have the option to own all Intellectual Property arising out of the Work done pursuant to this Agreement.
- 23.2 Subject to Article 23.6 of this Agreement, for all Intellectual Property created during Work under this Agreement, the appropriate Executive shall provide and obtain a non-exclusive, non-transferable, irrevocable, paid-up license (1) for use in ALMA and (2) for each of the Parties to use or have used on their behalf throughout the world for non-commercial research purposes of any such Intellectual Property.
- 23.3 The provisions of any NSF Award in connection with this Agreement, to AUI or any successor organization supporting the operations of the NRAO will, if applicable, contain the patent right provisions required by relevant U.S laws such as Chapter 18 of Title 35, United States Code, including a requirement as authorized by 35 USC 202 (c) (4) that the organization managing the NRAO provide or obtain, in addition to the license rights of the United States, a non-exclusive, nontransferable, irrevocable, paid-up license for ESO to practice or have practiced on their behalf throughout the world for research purposes any subject inventions. The license rights which the organization managing the NRAO will obtain for the United States under sub awards or other arrangements with persons or organizations from the ESO countries shall be limited to a non-exclusive, nontransferable, irrevocable, paid-up license for NSF to practice or have practiced on its behalf for research purposes any subject inventions created during Work under this Agreement. NSF or its appointed Executive shall provide corresponding license rights to ESO.
- 23.4 Arrangements made by the Executives for the undertaking of research or development work for ALMA may involve funding agreements that are not subject to Article 23.3 of this Agreement. The provisions of the NSF Award to AUI or any successor organization managing the NRAO, or provisions applied by ESO, will contain terms and conditions designed to assure the identification and reporting of inventions on a basis comparable to that contemplated under Article 23.3 of this Agreement and the granting of licenses to all affected Parties by the owner of the inventions that are substantially the same as those required for non-US Parties under Article 23.3 of this Agreement. When arrangements

involving its employees are made that are subject to this Article, the Party will have to enter into appropriate arrangements with the appropriate Executive to accomplish the intent of this Article.

- 23.5 In the case of scientific or technical papers, reports, books or similar materials (whether in print or electronic form) prepared by the Executives or their sub awardees and provided to the Parties or the Board, each Party shall be free to translate, reproduce and publicly distribute such materials, subject to any restrictions which may be placed on the document pursuant to Article 23.6 of this Agreement, or restrictions which are necessary to obtain appropriate protection of intellectual property rights in particular patents.
- 23.6 The Parties recognize that in some cases the Executives or their sub awardees may have to obtain goods or services from organizations that limit the uses made of certain technical data, software, know-how, or other information provided to the Executives or their sub awardees because the organization providing the data, software, know-how or other information treats it as proprietary or trade secret or otherwise restricts its use. This is likely to be particularly true where pre-existing technical data or software is involved. In such cases, the Parties recognize that it may not be cost-effective or possible for the Executives or their sub awardees to obtain license rights for the Parties of the type contemplated by Articles 23.2 and 23.5 of this Agreement and do not expect the Executives or their sub awardees to obtain such rights in such cases, provided that whatever license rights are obtained should be the same for both the Parties.

ARTICLE 24: LIABILITY

- 24.1 The Parties will ensure that the Executives procure and maintain for their own benefit, and at their own cost, comprehensive general liability insurance, as appropriate.
- 24.2 An Executive or Party sending information, materials, or supplies to another Executive, Party or Parties under this Agreement shall not be liable for damages of any nature, direct or indirect, to property of the Executive, Party or Parties receiving the information, materials, or supplies, or to any third party resulting from the use by the Executive, Party or Parties of the information, materials, or supplies received.

ARTICLE 25: NOTICE

- 25.1 Any notice contemplated by this Agreement, unless a different address is subsequently notified by one Party to the others in writing, must be sent to the addresses stated in Annex E to this Agreement, and copied to the Secretary to the Board, by either
- (a) certified mail or courier, and then it is considered to have been received ten days after it is sent; or
 - (b) electronic mail or facsimile, and then it is considered to have been received only when acknowledged by letter or facsimile.

ARTICLE 26: DISPUTES

- 26.1 The resolution of any disputes regarding the interpretation, implementation or application of this Agreement shall be sought by consultation between the Parties. Should such consultation fail, the matter shall be put to the Director of the National Science Foundation and the President of the ESO Council for resolution.

ARTICLE 27: ANNEXES

- 27.1 The following Annexes shall form an integral part of this Agreement:

- (a) Annex A: Project Description
- (b) Annex B: Scientific Requirements
- (c) Annex C: Project Time Schedule
- (d) Annex D: Work Breakdown Structure, Assignment of Deliverables and Schedule of Values
- (e) Annex E: Addresses of Parties and Board Members

**For the National
Science Foundation
of the United States:**

**For the European
Organisation for
Astronomical Research in
the Southern Hemisphere:**

Rita Colwell, Director
National Science
Foundation

Catherine Cesarsky
Director General, ESO

Date

Date

Place

Place

ANNEX A: PROJECT DESCRIPTION

Technical Overview

The Atacama Large Millimeter Array (ALMA) will be built and operated by a bilateral North-American European partnership. It is a millimeter-submillimeter wave interferometer consisting of 64 12m diameter antennas located on the Chajnantor Altiplano in the Atacama Desert of northern Chile. ALMA will be equipped with dual-polarization receivers covering 4 atmospheric windows: 84 - 116 GHz, 211 - 275 GHz, 275 - 370 GHz, and 602 - 720 GHz.

A tabular summary of the instrument's basic characteristics is shown in Table 1. Additional details are as follows:

Site: The site is in a region of the Altiplano in northern Chile known as Zona Chajnantor-Cerro Chascon with approximate coordinates 67.75° W, 23.02° S at an elevation of approximately 5000 m. The site land is administered by the Chilean Ministry of National Assets (*Bienes Nacionales*) and set aside by Presidential decree as a protected region for science. Measurements of the atmospheric transparency and stability made *in situ* continuously since 1995 confirm that the site has superior conditions for millimeter-wave and submillimeter-wave astronomy and that it will meet the requirements of the ALMA Project.

Antennas and Antenna Configurations: The antennas are 12 meter-diameter Cassegrain-fed paraboloids, with an aggregate rms surface error < 25 μ m. Each antenna is fully steerable and designed for rapid position-switching (up to 1.5 degrees in 1.5 seconds); more than 85 percent of the celestial sphere is visible from the Chajnantor site.

The antennas are all movable using a specially designed antenna transporter among 250 prepared antenna stations. Each station has a concrete foundation to support the antenna and provision for electrical power and data communications. Array configurations range from ~150 meters in diameter (for the study of large or low brightness objects) to ~14 km in extent (for the study of small, high brightness objects).

Front End Electronics: Each antenna will be equipped with four receiver cartridges – one for each frequency band – housed in a common 4K cryostat. All detectors are coherent, and rely upon a local oscillator signal phase-locked to an array frequency reference standard. Each receiver cartridge includes two receivers, operating in orthogonal senses of linear polarization. Off-axis from the Cassegrain focus of each antenna, a radiometer tuned to the 183 GHz atmospheric water vapor line will measure the column density of water above the antenna and enable the distorting effects of the water to be removed.

Table 1: ALMA Technical Summary

Array	
Number of Antennas (N)	64
Total Collecting Area ($\pi ND^2/4$)	7238 m ²
Total Collecting Length (ND)	768 m
Angular Resolution	0.2'' λ (mm)/baseline (km)
Array Configurations	
Compact: Filled	<i>{dimension of filled area}</i> 150 m
Continuous Zoom	200-5000 m
Highest Resolution	14.0 km
Total Number of Antenna Stations	250
Antennas¹	
Diameter (D)	12 m
Surface Accuracy	25 micrometers RMS
Pointing	0.6'' RSS in 9 m/s wind
Path Length Error	< 15 μ m during sidereal track
Fast Switch	1.5 degrees in 1.5 seconds
Total Power	Instrumented and gain stabilized
Transportable	By vehicle with rubber tires
Front Ends²	
84 - 116 GHz	<i>{All frequency bands}</i>
211 - 275 GHz	-Dual polarization
275 - 370 GHz	-Noise performance limited by atmosphere
602 - 720 GHz	-SiS
Water Vapor Radiometer	183 GHz
Intermediate Frequency (IF)	
Bandwidth	8 GHz, each polarization
IF Transmission	Digital
Correlator	
Correlated baselines	2016 (=64 * 63/2)
Bandwidth	16 GHz per antenna
Spectral Channels	4096 per IF
Data Rate	
Data Transmission from Antennas	120 Gb/s per antenna, continuous
Signal Processing at the Correlator	1.6×10^{16} multiply/add per second

¹The antenna specifications are detailed in Request for Proposals for a Prototype Antenna for the Millimeter Array/Large Southern Array, dated March 30, 1999.

²These four frequency bands are those required on the first-light ALMA as specified by the ALMA Science Advisory Committee at the committee meeting of March 11, 2000. Receivers in six additional atmospheric windows are deferred to future development.

Back End Electronics: Signals from each front end receiver will be converted to a common intermediate frequency (IF), amplified, and digitized at the antenna by the backend electronics. In order to process the 8 GHz bandwidth of the IF, the backend electronics will subdivide the IF into four 2 GHz sub-bands for transmission to the correlator.

Correlator: The correlator combines the digitized IF signals from each pair of antennas in the array, and creates astronomical images by Fourier transforming the complex phase and amplitude of the correlated signals. There are up to 2016 possible pairs of antennas in ALMA.

Organization: The system engineering, scientific oversight, and management necessary to coordinate the task activities of the ALMA technical team responsible for production of the ALMA technical system noted above are integral deliverables of the ALMA Project as well. The project safety office is included in the management function and reports directly to the ALMA Director.

Facilities and Infrastructure

ALMA will minimize the number of staff at the 5000m Array Operations Site (AOS), by relying as much as possible upon remote operations. Physical infrastructure at the AOS will consist of a central electronics and control building, an emergency refuge, and a meteorological building.

Other operating staff will be located at a lower altitude Operations Support Facility (OSF). Infrastructure at the OSF will consist of the antenna service building, array control building, electronic laboratories, and office, administrative and residential facilities. The OSF will be connected to the AOS by a road constructed to transport the antennas and the operations/maintenance staff, and a communications line of buried optical fibers through which the astronomical data and the instrument monitor data will be carried in real-time at high bandwidth.

ANNEX B: SCIENCE REQUIREMENTS

ALMA has three level-1 science requirements:

- 1) The ability to detect spectral line emission from CO or C+ in a normal galaxy like the Milky Way at a redshift of $z = 3$, in less than 24 hours of observation.
- 2) The ability to image the gas kinematics in a solar-mass protostellar/ protoplanetary disk at a distance of 150 pc (roughly, the distance of the star-forming clouds in Ophiuchus or Corona Australis), enabling one to study the physical, chemical, and magnetic field structure of the disk and to detect the tidal gaps created by planets undergoing formation.
- 3) The ability to provide precise images at an angular resolution of 0.1". Here the term *precise image* means accurately representing the sky brightness at all points where the brightness is greater than 0.1% of the peak image brightness. This requirement applies to all sources visible to ALMA that transit at an elevation greater than 20 degrees.

These requirements drive the technical specifications of ALMA. A highly simplified flow-down of science requirements into technical specifications can be given as follows:

- 1) High-redshift Galaxy Detection: The sensitivity of an array is primarily controlled by three major factors: total collecting area, the noise performance of the receivers, and atmospheric transparency and phase stability. The detection requirement for high-redshift galaxies, therefore has a direct impact on ALMA's collecting area, polarization and frequency requirements, and site.

Contemporary millimeter arrays have collecting areas between 500 and 1000 m² and can detect CO emission from the brightest high-redshift galaxies (which are amplified by gravitational lensing), in one to two days of observations; signals from normal, unlensed objects, will be typically 20-30 times fainter. Current millimeter-wave receiver technology has approached fundamental quantum limits, and the noise level of ALMA's detectors cannot be reduced beyond this point by much more than a factor of 2; an important additional factor of $\sqrt{2}$ in sensitivity is gained by requiring that ALMA support front-end instrumentation capable of measuring both states of polarization. The proposed ALMA site will minimize the noise contributions of the atmosphere, so that the remaining factor of 7-10 in sensitivity can only be gained by increasing the collecting area of the area by a similar amount. Hence, ALMA must have at least 7000 m² in collecting area.

The molecular spectral lines which generally serve as diagnostics of the gas content and dynamics of galaxies early in the history of the Universe have frequencies that are fixed in the rest frame of the galaxy, but will be observed at frequencies that depend upon redshift. Since galaxies are found at every redshift (i.e., *age*) ALMA should ideally provide access to all atmospheric windows from

30-950 GHz, so that galaxies of all ages may be studied. Initially, however, the array will support observations in the four highest-priority frequency bands. Additional capabilities may be added in the operational phase of ALMA. Since the redshift of the galaxies will initially be essentially unknown, the instantaneous bandwidths of the receivers and the correlator should also be as large as possible; this will also maximize the continuum sensitivity of the array.

2. Protoplanetary/Protostellar Disks: These requirements have impacts on ALMA operating frequency, baseline size, frequency resolution, and polarization.

Theoretical calculations indicate that the gaps created by Jupiter-mass objects in protoplanetary disks will be ~ 1 AU in extent. Combined with the distance to the nearest star-forming regions (60-150 pc), the requirement that such gaps be resolvable in protoplanetary disks implies an angular resolution of $0.010''$ or better. This can be achieved by combining high frequency ($\nu > 650$ GHz) observations with array baselines of at least 10 km. Proper study of the kinematics of the disk images further requires that spectroscopy be carried out at velocity resolutions finer than 0.05 km/s. As a result, the spectral resolution provided by the ALMA correlator must be as small as a few tens of kHz. The study of the magnetic field and its properties in disks requires that the ALMA receiving systems are equipped with full polarization capability in order to measure all the Stokes parameters.

3. Precise Imaging. The requirement for high fidelity imaging constrains the number of antennas in the array, since a sufficient number of baselines to cover adequately the uv plane (i.e., the time/frequency domain plane in which the data are sampled) is required. Detailed studies of the imaging performance of aperture synthesis arrays have shown that the requisite imaging performance implies a minimum number of antennas, 40 or above, and accurate measurements of the shortest baselines, as well as of the large scale emission measured by total power from the antennas. Such accurate measurements can only be obtained with high quality antennas, with superior pointing precision. High fidelity imaging also requires the ability to perform calibrations to "freeze" the atmospheric turbulence which distorts the radiation coming from celestial sources.

The combination of these three major requirements calls for a reconfigurable zoom-lens array covering baselines from a few meters up to several kilometers, observing over the full millimeter and submillimeter atmospheric windows. The maximum size of the individual antennas is driven by the required pointing and surface precision: a choice of 12-m antennas offers an excellent technological compromise. To provide no less than 7000 m^2 of total collecting area, 64 antennas are needed, which is a large enough number to guarantee excellent imaging performance. Dual polarization is mandatory to provide enough sensitivity in

spectral line mode. ALMA will offer a full-polarization mode to offer new capabilities to the astronomical community.

To minimize the impact of atmospheric noise, a dry site with minimal attenuation, but also with high phase stability as been selected. The ALMA site has been monitored for more than 7 years in order to assure that it is optimal from both standpoints. However, because ALMA will have kilometer-long baselines, more active measures will be required to cancel the effects of the atmospheric disturbances. To do this, each ALMA antenna will be equipped with a Water Vapor Radiometers (WVR) to measure atmospheric path length variations and correct the image distortions which such phase variations create.

The final major scientific requirement affects the diverse community that will use and benefit from the scientific capabilities that ALMA brings to extend their research endeavors: ALMA should be "easy to use" by novices and experts alike. Astronomers certainly should not need to be experts in aperture synthesis to use ALMA. Automated image processing will be developed and applied to most ALMA data, with only the more intricate experiments requiring expert intervention.

ANNEX C: PROJECT TIME SCHEDULE – MAJOR MILESTONES

Milestone or Deliverable	Date
Start antenna evaluation at ALMA Test Facility	Q4 2002
Begin Initial Phase of Civil Works in Chile	Q4 2003
Central Back End System ready to install at Array Site	Q1 2005
Initial Phase of Civil Works in Chile Complete	Q2 2005
First Antenna-based Backend Subsystem ready for installation at OSF	Q2 2005
First Production Antenna available in Chile at OSF	Q4 2005
Initial Front End Subsystem available at OSF	Q4 2005
Start Early Science Observations	Q3 2007
Completion of Construction Project	Q4 2011
Start Full Science Operations	Q1 2012

ANNEX D: WORK BREAKDOWN STRUCTURE, ASSIGNMENT OF DELIVERABLES AND SCHEDULE OF VALUES

Work Breakdown Structure

The ALMA Work Breakdown Structure (WBS) is a detailed description of all the tasks necessary to construct the instruments and software required for ALMA; to construct the buildings, roads, antenna foundations, utilities and infrastructure needed for the support of those instruments and software; to integrate the whole into a properly functioning synthesis array telescope on the Chajnantor site in northern Chile; and to manage the construction project on behalf of the two sponsoring ALMA Parties via work carried out through NRAO ("North America") and ESO ("Europe").

The ALMA construction project has adopted a management structure based on the Integrated Product Team (IPT) concept. The IPT concept provides a method of managing tasks carried out across multiple organizations and locations. Each level-1 WBS element is managed by an IPT responsible for delivering the required products on time, within the specified cost and meeting the project requirements. The implementation of the IPT concept is described in the ALMA Management Plan.

The ALMA WBS was derived in three steps. First, the scientific requirements for ALMA were specified by the ALMA Science Advisory Committee (ASAC). Second, a technical description of an array capable of meeting those requirements was outlined by the technical leaders of the ALMA Project in North America and Europe. Close and frequent interaction was required between the ASAC and the technical project leadership to assure that the planned technical capabilities met the science requirement priorities. Third, a plan for design and fabrication, or procurement, of all the hardware modules and subsystems was established. Costs were estimated for all tasks and subtasks. The process was informed and constrained by the estimated resources the sponsors were intending to commit to ALMA. The resulting project description was organized into the WBS which specifies in sufficient detail the tasks and the resources, both personnel and financial, required to realize those tasks for the completed project.

The WBS for the ALMA construction project down to level 3 is included in the following pages. The WBS is organized into nine level-1 tasks:

1. Management/Administration (*)
2. Site Development
3. Antenna Subsystem
4. Front End Subsystem
5. Back End Subsystem
6. Correlator
7. Computing Subsystem
8. System Engineering and Integration
9. Science (*)

* Note: Education and Public Outreach is a functional task of the Science IPT and Safety is a task of Management/Administration.

WBS	Task	NA %	Eur %	Responsibility
	ALMA Project Plan 2002Mar12			
1	<u>Management / Admin.</u>			
1.010	<u>Management And Administration</u>			JAO
1.010.0100	North American Project Office	100%		
1.010.0120	European Project Office		100%	
1.015	<u>Joint ALMA Office</u>			JAO
1.015.0180	Joint ALMA Office (Including safety)	50%	50%	
2	<u>Site Development</u>			
2.020	<u>Site Construction Management</u>			Site IPT
2.020.0200	Site Development Management	35%	65%	
2.025	<u>Site Development</u>			Site IPT
2.025.0210	Site infrastructure	71%	29%	
2.025.0220	Array Site	49%	51%	
2.025.0240	Operations Support Facility (OSF)	0%	100%	
2.025.0260	Array/OSF Access Roads	33%	67%	
2.025.0280	Array/OSF Communication Links	100%	0%	
2.025.0300	Chilean Phase 2 Facilities	0%	100%	
3	<u>Antenna Subsystem</u>			
3.030	<u>Antenna Management/Engineering</u>			Ant IPT
3.030.0320	Antenna Management Phase 2	50%	50%	
3.030.0340	Production Antenna Engineering Support	50%	50%	
3.035	<u>Prototype Antenna Evaluation Support</u>			Ant IPT
3.035.0360	North Am. Post Acceptance Evaluation	100%		
3.035.0380	Euro Post Acceptance Evaluation		100%	
3.036	<u>European Prototype Antenna Phase 2</u>			Europe
3.036.0410	European Phase 2 Prototype Antenna		100%	
3.045	<u>Antenna Contract Tendering/Supervisor</u>			Ant IPT
3.045.0440	Final Design Mods & Documentation; Prepare Bid Package	50%	50%	
3.045.0460	Production Antenna Contracting	50%	50%	
3.045.0480	Final Foundation Design	50%	50%	
3.050	<u>Antenna Procurement</u>			Ant IPT
3.050.0500	Production Antennas	49%	51%	
3.060	<u>Production Antenna Acceptance at OSF</u>			Ant IPT
3.060.0680	Production Antenna Acceptance at OSF	50%	50%	
3.065	<u>Nutator Design/Fabricate</u>			N. Am.
3.065.0580	Production Antenna Nutator	100%		
3.070	<u>Transporter Design/Fabricate</u>			Europe
3.070.0600	Transporter Design / Fabrication		100%	
4	<u>Front End Subsystem</u>			
4.075	<u>Frontend Management/Subsystem Engineering</u>			FE IPT
4.075.0620	Front End Subsystem Management	50%	50%	
4.075.0640	Front End Subsystem Engineering	50%	50%	
4.080	<u>Cryostat Design/Prototype</u>			Europe
4.080.0660	Cryostat Design/Prototype		100%	
4.085	<u>Cryostat Production</u>			Europe
4.085.0680	Cryostat construction		100%	

ALMA Construction Plan 2002-Mar-12		ALMA Project_2002Mar12r08.mpp		
All Tasks selected		View: Import Gantt View		
Construction Plan: Page 2 of 6				
WBS	Task	NA %	Eur %	Responsibility
4.085.0700	Cryocooler		100%	
<u>4.090</u>	<u>Windows/IR/Common Optics Design/Prototype</u>			<u>Europe</u>
4.090.0720	Windows/IR/Common Optics Design/Prototype		100%	
<u>4.095</u>	<u>Windows/IR/Common Optics Production</u>			<u>Europe</u>
4.095.0740	Common Optics		100%	
4.095.0760	Windows and IR Filters		100%	
<u>4.100</u>	<u>Electronics/M&C Design/Prototype</u>			<u>N. Am.</u>
4.100.0780	FE Electronics / M&C Design/Prototype	100%		
<u>4.105</u>	<u>Electronics/M&C Production</u>			<u>N. Am.</u>
4.105.0800	Production Front End Electronics	100%		
4.105.0820	Front-end IF Selection Switch	100%		
4.105.0840	Front End Monitor and Control System	100%		
<u>4.110</u>	<u>FE Subreflector Calibration System Development</u>			<u>N. Am.</u>
4.110.0860	Photonic Phase Cal Development	100%		
<u>4.115</u>	<u>FE Focal Plane Calibration System Development</u>			<u>Europe</u>
4.115.0890	Calibration System Development		100%	
<u>4.120</u>	<u>FE Subreflector Calibration System Production</u>			<u>N. Am.</u>
4.120.0900	Photonic Phase Cal Production	100%		
4.120.0940	Subreflector Calibration System - control s/w and h/w	100%		
4.120.0960	Subreflector Calibration System - hardware at subreflector	100%		
<u>4.125</u>	<u>FE Focal Plane Calibration System Production</u>			<u>Europe</u>
4.125.0920	Calibration System		100%	
4.125.0980	Solar Filter		100%	
<u>4.140</u>	<u>Band 3 Cartridge Design/ Prototype</u>			<u>N. Am.</u>
4.140.1003	Band 3 Cartridge Design / Development	100%		
<u>4.145</u>	<u>Band 3 Cartridge Production</u>			<u>N. Am.</u>
4.145.1063	Signal and LO Sources Band 3	100%		
4.145.1080	Band 3 SIS Mixer	100%		
4.145.1103	LO Production Band 3	100%		
4.145.1123	SIS Mixer Production Equipment Band 3	100%		
4.145.1140	IF amplifier 4-12 GHz (Band 3 SIS option only)	100%		
4.145.1163	Build SIS mixer fabrication equipment Band 3	100%		
4.145.1180	Band 3 - SIS mixer option: Other components	100%		
4.145.1203	Cartridge Body construction Band 3		100%	
4.145.1303	Cartridge test cryostat Band 3		100%	
4.145.1403	SIS Junctions Band 3	100%		
<u>4.160</u>	<u>Band 6 Cartridge Design/ Prototype</u>			<u>N. Am.</u>
4.160.1006	Band 6 Cartridge Design / Development	100%		
<u>4.165</u>	<u>Band 6 Cartridge Production</u>			<u>N. Am.</u>
4.165.1066	Signal and LO Sources Band 6	100%		
4.165.1106	LO Production Band 6	100%		
4.165.1106	LO Production Diode Multipliers Band 6	100%		
4.165.1126	SIS Mixer Production Equipment Band 6	100%		
4.165.1166	Build SIS mixer fabrication equipment Band 6	100%		
4.165.1206	Cartridge Body construction Band 6		100%	
4.165.1240	Band 6 SIS Mixer	100%		
4.165.1280	Production Band 6 Orthomode Transducer (OMT)	100%		

WBS	Task	NA %	Eur %	Responsibility
4.165.1280	14 IF amplifier 4-12 GHz (Band 6 only)	100%		
4.165.1306	Cartridge test cryostat Band 6		100%	
4.165.1320	Band 6 Other components	100%		
4.165.1406	SIS Junctions Band 6	100%		
<u>4.170</u>	<u>Band 7 Cartridge Design/ Prototype</u>			<u>Europe</u>
4.170.1007	Band 7 Cartridge Design / Development		100%	
<u>4.175</u>	<u>Band 7 Cartridge Production</u>			<u>Europe</u>
4.175.1107	LO Production Band 7	100%		
4.175.3107	LO Production Diode Multipliers Band 7	100%		
4.175.1207	Cartridge Body construction Band 7		100%	
4.175.1307	Cartridge test cryostat Band 7		100%	
4.175.1340	Band 7 Internal optics, feed & polarizer baseline		100%	
4.175.1360	Band 7 SIS Mixer baseline		100%	
4.175.1407	SIS Junctions Band 7		100%	
4.175.1420	Band 7 Other Components baseline		100%	
<u>4.190</u>	<u>Band 9 Cartridge Design/ Prototype</u>			<u>Europe</u>
4.190.1009	Band 9 Cartridge Design / Development		100%	
<u>4.195</u>	<u>Band 9 Cartridge Production</u>			<u>Europe</u>
4.195.1109	LO Production Band 9	100%		
4.195.3109	LO Production Diode Multipliers Band 9	100%		
4.195.1209	Cartridge Body construction Band 9		100%	
4.195.1309	Cartridge test cryostat Band 9		100%	
4.195.1409	SIS Junctions Band 9		100%	
4.195.1460	Band 9 cartridge parts (excl. mixer)		100%	
4.195.1460	Band 9 fabrication equipment Part 1		100%	
4.195.1500	Band 9 fabrication equipment Part 2		100%	
4.195.1520	Band 9 mixer		100%	
<u>4.210</u>	<u>WVR Radiometer Design/ Prototype</u>			<u>Europe</u>
4.210.1011	WVR Cartridge Design / Development		100%	
<u>4.215</u>	<u>WVR Radiometer Production</u>			<u>Europe</u>
4.215.1560	163GHz WVR Production, Installation & Commissioning		100%	
<u>4.220</u>	<u>Integration Test Facilities Develop/Procure</u>			<u>N. Am.</u>
4.220.1580	Front End Test Station Development	100%		
<u>4.225</u>	<u>Integration Test Facilities Duplicate</u>			<u>Europe</u>
4.225.1600	Front End Test Station Replication		100%	
<u>4.230</u>	<u>Frontend Integration</u>			<u>N. Am.</u>
4.230.1620	Front End Integration Center #1 Setup and Operation	100%		
4.230.1630	Front End Integration Center #2 Setup and Operation		100%	
<u>4.235</u>	<u>Frontend Mechanical Chassis/Mount</u>			<u>N. Am.</u>
4.235.1660	Front End Chassis	50%	50%	
<u>4.240</u>	<u>Front End Service Vehicle</u>			<u>N. Am.</u>
4.240.1680	Front End Service and Exchange Vehicle	100%		
<u>4.245</u>	<u>Photonic LO Development</u>			<u>N. Am.</u>
4.245.1700	Photonic LO Development N. Am.	100%		
4.245.1705	Photonic LO Development Europe		100%	
<u>4.250</u>	<u>LO Driver Development</u>			<u>N. Am.</u>
4.250.1720	LO driver continued development section	100%		

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All Tasks selected

WBS	Task	NA %	Eur %	Responsibility
4.250.1740	Cold multiplier continued development section	100%		
<u>4.255</u>	<u>Multiplier/Driver Production</u>			<u>N. Am.</u>
4.255.1760	LO Multiplier Drivers fabrication and test	100%		
4.255.1800	Cold multiplier fabrication and test equipment	100%		
<u>5</u>	<u>Backend Subsystem</u>			
<u>5.260</u>	<u>Backend Management Subsystem Engineering</u>			<u>BE IPT</u>
5.260.1880	Backend Mgm/Subsystem Engineering Phase 2	75%	25%	
5.260.1840	LO Ref Engineering Field Support	100%		
5.260.1860	Photonic Dist Engineering Support	100%		
5.260.1900	Backend Engineering Support	67%	33%	
<u>5.265</u>	<u>Backend Analog Processing Design/Prototype</u>			<u>N. Am.</u>
5.265.1920	Prototype System IF Down-converter	100%		
<u>5.270</u>	<u>Backend Analog Processing Production</u>			<u>N. Am.</u>
5.270.1940	IF Down-converter	100%		
5.270.1960	Power Supply Modules	100%		
5.270.1980	BE Production Test & Lab Equipment	100%		
<u>5.275</u>	<u>Backend Digitizer Design/Prototype</u>			<u>Europe</u>
5.275.2000	Backend Digitizer/Sampler Prototype		100%	
<u>5.280</u>	<u>Backend Digitizer Production</u>			<u>Europe</u>
5.280.2020	Digitizer/Sampler		100%	
5.280.2040	DeMultiplexer for Digitizer/Sampler		100%	
<u>5.285</u>	<u>Backend Data Transmission Design/Prototype</u>			<u>N. Am.</u>
5.285.2060	Prototype System Digital IF Tx & Rx	50%	50%	
<u>5.290</u>	<u>Backend Data Transmission Production</u>			<u>N. Am.</u>
5.290.2080	Sampler Clock		100%	
5.290.2100	Digital IF Transmitters and Receivers	25%	75%	
<u>5.295</u>	<u>LO Frequency Synthesis Design/Prototype</u>			<u>N. Am.</u>
5.295.2120	LO Reference Prototype	100%		
5.295.2140	FO Transmitter, LO Ref - Low Freq	100%		
<u>5.300</u>	<u>LO Frequency Synthesis Production</u>			<u>N. Am.</u>
5.300.2160	FO Receiver, LO Reference	100%		
5.300.2180	Two-Laser generator, RF synthesizer	100%		
5.300.2200	Second LO Synthesizer	70%	30%	
5.300.2220	Fringe Generator	100%		
5.300.2240	Central LO Reference Generator	100%		
5.300.2260	H-maser Frequency Standard		100%	
5.300.2280	Power Supply Modules	100%		
5.300.2300	LO Ref Production supervision & int.	100%		
5.300.2320	LO Ref Production test & lab equipment	100%		
5.300.2335	Photonic Dist Prototype	100%		
5.300.2340	Fabricate Photonic Dist Production System	50%	50%	
<u>5.305</u>	<u>Backend Installation/Integration in Chile</u>			<u>BE IPT</u>
5.305.2360	LO Reference On Site Integration and Test	50%	50%	
5.305.2380	Photonic Dist On Site Integration and Test	50%	50%	
5.305.2400	Backend On Site Integration and Test	50%	50%	
<u>6</u>	<u>Correlator</u>			
<u>6.310</u>	<u>Correlator Management/Subsystem Engineering</u>			<u>Corr IPT</u>

ALMA Construction Plan 2002-Mar-12
All Tasks selected

WBS	Task	NA %	Eur %	Responsibility
6.310.2420	Baseline Correlator Mgmt/Subsystem Engineering Phase 2	100%		
6.310.2440	Baseline Correlator Continued Support	100%		
<u>6.315</u>	<u>Baseline Correlator Design/Prototype</u>			<u>N. Am.</u>
6.315.2460	Prototype Correlator Production	100%		
<u>6.320</u>	<u>Baseline Correlator Production</u>			<u>N. Am.</u>
6.320.2480	First 1/4 correlator	100%		
6.320.2500	Second 1/4 correlator	100%		
6.320.2520	Third 1/4 correlator	100%		
6.320.2540	Fourth 1/4 correlator	100%		
<u>6.325</u>	<u>Second Generation Correlator Design/Prototype</u>			<u>Europe</u>
6.325.2570	Second Generation Correlator Development		100%	
<u>7</u>	<u>Computing Subsystem</u>			
<u>7.340</u>	<u>Computing</u>			<u>Com IPT</u>
7.340.2640	Computer Subsystem Management	63%	38%	
7.340.2660	Computing Hardware	50%	50%	
7.340.2680	Science Software Requirements	44%	56%	
7.340.2700	High Level Analysis & Design	44%	56%	
7.340.2720	Software Engineering	42%	58%	
7.340.2740	Common Software	43%	57%	
7.340.2750	Executive Software		100%	
7.340.2760	Control Software	81%	19%	
7.340.2780	Correlator Software	100%		
7.340.2800	Pipeline Software	65%	35%	
7.340.2820	Archiving	24%	76%	
7.340.2840	Scheduling	100%		
7.340.2860	Observing Preparation & Support		100%	
7.340.2880	Off-line Data Processing/Analysis	70%	30%	
7.340.2890	Data Reduction User Interface		100%	
7.340.2900	Telescope Calibration		100%	
7.340.2920	Integration, Test & Support	53%	47%	
<u>8</u>	<u>System Eng. & Integration</u>			
<u>8.360</u>	<u>System Engineering Management</u>			<u>Svs IPT</u>
8.360.2940	SE&I Management	50%	50%	
<u>8.365</u>	<u>System Engineering Development Support</u>			<u>Svs IPT</u>
8.365.2960	Phase 2 System Engineering	50%	50%	
<u>8.370</u>	<u>Test Interferometer Support</u>			<u>Svs IPT</u>
8.370.2980	ALMA Prototype Antenna Evaluation	50%	50%	
8.370.3000	Prototype ALMA System Integration	50%	50%	
<u>8.375</u>	<u>System Validation, Integration, Acceptance</u>			<u>Svs IPT</u>
8.375.3020	ALMA System Integration	50%	50%	
<u>9</u>	<u>Science</u>			
<u>9.380</u>	<u>Science</u>			<u>Sci IPT</u>
9.380.3040	Phase 2 Science Support	50%	50%	
<u>9.385</u>	<u>Education and Public Outreach</u>			<u>Executives</u>
9.385.3060	North American EPO	100%		
9.385.3080	European EPO		100%	
9.385.3100	Chilean EPO			

Assignment of Deliverables

As stated in Article 2 of the Agreement, NSF and ESO will make equal value contributions to ALMA with the work equally and equitably shared between them. Therefore, the level-3 tasks, i.e., deliverables, were divided in a manner that (a) led to an equal assignment of value to both sides; (b) led to a division of equal risk to both sides, as measured by contingency; and (c) respected particular institutional experience on both sides. The resulting assignment of deliverables is presented in the WBS for each level-3 task as a percentage division between Europe and North America.

Task responsibility is assigned at WBS level-2. This is noted for each task in the final (right-most) column in the WBS. The level-2 tasks are referred to as work packages that the responsible partner may wish to assign to one of its participating institutions. Each work package is subdivided into work elements. These are the level-3 tasks to which value is assigned. Usually the work elements are assigned wholly to one partner or the other. In the case of shared level-3 tasks the division of effort as 100 percent to one side or another is made at a still lower level. This information is given on the individual ALMA Work Element sheets that are not included here.

Schedule of Values

Costs and contingencies were developed for each subtask of the WBS and rolled up as the summed costs of tasks; the task costs were subsequently rolled up as the summed Project cost. The basis for the cost estimates was a bottom-up sum of the costs associated with each subtask of the project-wide WBS. The European and North American technical leaders, working together, developed estimates for the entire task product tree using a standard ALMA Cost Data Sheet that asked the technical leaders to provide for each task:

- Task description;
- Task duration (or start and stop dates and predecessor tasks);
- Currency used for materials, supplies and contract expense;
- Basis of the estimate;
- Contingency;
- Staff Effort;
- List of materials and estimated cost of each;
- List of contracts and estimated cost of each;
- Cost parameterization.

Personnel costs are fully burdened costs. That is, the personnel costs include personnel benefits and a percentage of institutional indirect costs. The institutional indirect cost is a uniform percentage derived from the major partner institutions; this is done to make the personnel cost independent of where the work is performed.

Contingency was separately calculated for each subtask. The contingency methodology used was a bottom-up computation of the sum of three separately calculated contingencies. These three contingencies correspond to three different risk factors: the technical risk (how difficult is the task?), the cost risk (what is the uncertainty on the cost?), and the schedule risk (how does this task affect the overall schedule?). Estimators evaluated the technical, cost and schedule risk factors for a particular WBS task and then entered those factors in the ALMA Cost Data Sheets.

The value of a level-3 task is the sum of the cost and contingency for that task. An ALMA partner executing a particular level-3 task will receive for the successful delivery of that task credit for the value assigned in the WBS. The partner has the discretion to carry out the task in the manner the partner chooses to be in its best interest, but the value is not affected by that choice.

A summary of costs (in thousands of FY 2000 dollars), contingencies, and values (in thousands of FY 2002 dollars) by level-1 WBS task for the construction project is given in the following table. The table also shows the division of values by WBS area between North America and Europe.

Schedule of Values and Cost Summary for ALMA Phase 2 Construction (Y2000 K\$)

Level-1 WBS Task	Total Project			North American Tasks			European Tasks		
	Cost	Contingency	Value	Cost	Contingency	Value	Cost	Contingency	Value
1. Management/Administration	\$16,470	5.1%	\$17,313	\$8,440	5.0%	\$8,861	\$8,030	5.3%	\$8,452
2. Site Development	\$61,154	14.6%	\$70,049	\$23,418	14.4%	\$26,787	\$37,736	14.6%	\$43,262
3. Antenna Subsystem	\$198,022	15.0%	\$227,739	\$96,925	14.8%	\$111,299	\$101,097	15.2%	\$116,440
4. Front End Subsystem	\$90,800	20.0%	\$108,982	\$43,886	21.4%	\$53,291	\$46,914	18.7%	\$55,691
5. Back End Subsystem	\$40,777	22.0%	\$49,765	\$24,004	18.4%	\$28,416	\$16,773	27.3%	\$21,349
6. Correlator	\$13,204	12.5%	\$14,856	\$12,675	12.8%	\$14,294	\$529	6.2%	\$562
7. Computing Subsystem	\$29,843	15.5%	\$34,468	\$15,905	14.4%	\$18,199	\$13,938	16.7%	\$16,269
8. System Eng. & Integration	\$18,172	10.8%	\$20,125	\$9,358	10.4%	\$10,335	\$8,814	11.1%	\$9,790
9. Science	\$8,721	5.2%	\$9,173	\$4,527	5.0%	\$4,753	\$4,194	5.4%	\$4,420
Total	\$477,163	15.8%	\$552,470	\$239,138	15.5%	\$276,235	\$238,025	16.1%	\$276,235

ANNEX E: ADDRESSES OF PARTIES AND BOARD MEMBERS

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