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LIGO.4.07 Auxiliary Optics (AOS)

LIGO.4.07.1 AOS Subsystem Management

LIGO.4.07.2 AOS R&D

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BL Advanced LIGO
Baseline Rev. 05.22.03
LIGO Laboratory Program
WBS



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Level 3 Grouping: LIGO.4.06

WBS No.	WBS Description
LIGO.4.06	Core Optics Components (COC)
WBS Definition	
<p>This is a summary level WBS element only.</p> <p>The Core Optics Components (COC) consist of all of the optics used to form the power recycling, signal recycling and Fabry-Perot cavities of the interferometer. It does not include optics for input or output mode cleaners, the mode match telescope, auxiliary optics (steering mirrors, optical signal pick-off mirrors, etc.) or other masses used in the suspended pendulum. As a consequence the core optics consists specifically of the following optical components:</p> <ol style="list-style-type: none">1) End Test Mass (ETM)2) Input Test Mass (ITM)3) Folding Mirror (FM; for the 2nd interferometer at the Hanford Observatory only)4) Beam Splitter (BS)5) Power Recycling Mirror (PRM)6) Signal Recycling Mirror (SRM)	
WBS Author	WBS Date
G. Billingsley	04/30/2001

WBS No.	WBS Description
LIGO.4.06.1	COC Subsystem Management
WBS Definition	
<p>This is a Level of Effort (LOE) WBS element.</p> <p>All COC subsystem management, technical direction, interface liaison and oversight labor are covered under this WBS element. This includes all consulting support which is not attributable to a specific WBS element.</p>	
WBS Author	WBS Date
G. Billingsley	04/30/2001

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WBS No.	WBS Description
LIGO.4.06.2	COC R&D
WBS Definition	
<p>This is a summary level WBS element only. All fundamental, applied and process or fabrication development research for the COC is covered under this WBS</p> <p>element. This includes all R&D by members of the LIGO Scientific Collaboration (LSC).</p>	
WBS Author	WBS Date
G. Billingsley	04/30/2001

WBS No.	WBS Description
LIGO.4.06.2.1	Core Optics Development - Caltech (COC)
WBS Definition	
<p>The fabrication process development and vendor source evaluation for LIGO-II core optics is covered under this WBS</p> <p>element. This WBS element does not include sapphire material R&D (covered under WBS element 0.4.6.2.2 and 0.4.6.2.4), nor does it include the Pathfinder-II full scale manufacturing demonstration (covered under WBS element 0.4.6.3.4).</p> <ul style="list-style-type: none"> · Coating: Evaluation and development of alternate ion beam puttering (IBS) coating sources with the capability of meeting LIGO low loss and uniformity requirements. · Cleaning: Development of improved optics cleaning techniques and tooling · Metrology: Improvements in the core optics surface characterization metrology. · Low Absorption Fused Silica: Evaluation and development of alternate low absorption, fused silica material sources. <p>This effort is separate from the fabrication WBS element (0.4.6.3.4) because of the exceedingly long time required to develop the capability to meet LIGO requirements and the research, or high risk, nature of the processing/fabrication development.</p>	
WBS Author	WBS Date
G. Billingsley	04/30/2001

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WBS No.	WBS Description
LIGO.4.06.2.2	Sapphire Core Optics R&D- Stanford
WBS Definition	
<p>This is a summary level WBS element only. All of the Stanford R&D related to the COC are covered below. These activities are defined in Attachment B of the MOU between Stanford and the LIGO Lab (M990329-00), section 8, paragraphs (a) and (f).</p>	
WBS Author	WBS Date
G. Billingsley	04/30/2001
WBS No.	WBS Description
LIGO.4.06.2.2.1	Coating Effect on Q Tests
WBS Definition	
<p>These activities are defined in Attachment B of the MOU between Stanford and the LIGO Lab (M990329-00), section 8, paragraphs (a) and (f).</p>	
WBS Author	WBS Date
G. Billingsley	04/30/2001
WBS No.	WBS Description
LIGO.4.06.2.2.2	Absorption Dependence Upon Materials and Origin
WBS Definition	
<p>These activities are defined in Attachment B of the MOU between Stanford and the LIGO Lab (M990329-00), section 8, paragraph (a). Actually the MOU doesn't really address this area of research; Is it considered done? Now being done by CIT?</p>	
WBS Author	WBS Date
G. Billingsley	04/30/2001

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WBS No.		WBS Description	
LIGO.4.06.2.3		Core Optics Development - GEO	
WBS Definition			
Not applicable; All collaborative research defined in Attachment B of the MOU between GEO and the LIGO Lab (M000038-00) is related to Suspensions (SUS).			
WBS Author		WBS Date	
G. Billingsley		04/30/2001	

WBS No.		WBS Description	
LIGO.4.06.2.4		Sapphire Core Optics R&D - Caltech (SAP)	
WBS Definition			
This is a summary level WBS element only. All of the Caltech R&D related to the development of sapphire COC, other than the Pathfinder-II fabrication related development efforts under WBS 0.4.6.2.1, are covered below. This research is defined in LIGO document #? (Advanced R&D Plan document?)			
WBS Author		WBS Date	
G. Billingsley		04/30/2001	

WBS No.		WBS Description	
LIGO.4.06.2.4.1		Polish Effect on Q Tests	
WBS Definition			
WBS Author		WBS Date	

WBS No.		WBS Description	
LIGO.4.06.2.4.2		Coating Absorption and Birefringence Tests	
WBS Definition			
WBS Author		WBS Date	

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WBS No.		WBS Description	
LIGO.4.06.2.4.3		Coating Birefringence Tests	
WBS Definition			
WBS Author		WBS Date	

WBS No.		WBS Description	
LIGO.4.06.2.4.4		SIOM Crystal Growth Development	
WBS Definition			
WBS Author		WBS Date	

WBS No.		WBS Description	
LIGO.4.06.3		COC Design	
WBS Definition			
WBS Author		WBS Date	

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WBS No.	WBS Description
LIGO.4.06.3.1	COC Conceptual Design/Requirements
WBS Definition	
<p>All design and development activities up to and including the COC Conceptual Design Review (CDR) are covered under this WBS element (except for associated R&D covered under WBS elements 0.4.6.2). The principal deliverables for this WBS element are as follows:</p> <p>1a) Design Requirements Document for Core Optics Components (COC) with Sapphire Fabry-Perot Cavity Optics</p> <p>1b) Conceptual Design Document for Core Optics Components (COC) with Sapphire Fabry-Perot Cavity Optics</p> <p>2a) Design Requirements Document for Fused Silica Core Optics Components (COC)</p> <p>2b) Conceptual Design Document for Fused Silica Core Optics Components (COC)</p> <p>Documents 1a) and 1b) are for the baseline interferometer with sapphire optics for the Input Test Masses (ITM) and End Test Masses (ETM) with all other core optics fabricated from fused silica. Documents 2a) and 2b) are for the fall-back option of an interferometer with only fused silica core optics. The requirements and conceptual design should be supported by detailed optical analyses of the interferometer response in coordination with the Systems Engineering group. Interface definition between the COC and the Suspension (SUS) and the Active Optics Compensation (AOC) subsystems should be defined in the requirements documents as well. Completion of the CDR milestone marks the end of this WBS element. Preparation for , presentation of, and follow-up response to, the Conceptual Design Review (CDR) is also part of this WBS element.</p>	
WBS Author	WBS Date
G. Billingsley	04/30/2001

Advanced LIGO - WBS Dict. Report

WBS No.	WBS Description
LIGO.4.06.3.2	COC Preliminary Design
WBS Definition	
<p>All design and development activities up to and including the COC Preliminary Design Review (PDR) are covered under this WBS element (except for associated R&D covered under WBS elements 0.4.6.2). The principal deliverables for this WBS element are as follows:</p> <p>1a) Design Requirements Document for Core Optics Components (COC) with Sapphire Fabry-Perot Cavity Optics 1b) Preliminary Design Document for Core Optics Components (COC) with Sapphire Fabry-Perot Cavity Optics 2a) Design Requirements Document for Fused Silica Core Optics Components (COC) 2b) Preliminary Design Document for Fused Silica Core Optics Components (COC)</p> <p>Documents 1a) and 1b) are for the baseline interferometer with sapphire optics for the Input Test Masses (ITM) and End Test Masses (ETM) with all other core optics fabricated from fused silica. Documents 2a) and 2b) are for the fall-back option of an interferometer with only fused silica core optics. The requirements and conceptual design should be supported by detailed optical analyses of the interferometer response in coordination with the Systems Engineering group. Interface definition between the COC and the Suspension (SUS) and the Active Optics Compensation (AOC) subsystems should be defined in the requirements documents as well. Completion of the PDR milestone marks the end of this WBS element. Preparation for , presentation of, and follow-up response to, the Preliminary Design Review (CDR) is also part of this WBS element. It also serves as a summary WBS element for all COC preliminary design phase activities.</p>	
WBS Author	WBS Date
G. Billingsley	04/30/2001

Advanced LIGO - WBS Dict. Report

WBS No.	WBS Description
LIGO.4.06.3.2.1	Optics Design
WBS Definition	
<p>The activities leading to a complete definition of the optical prescription for the core optics are covered under</p> <p>this WBS element. The deliverables of this WBS element are:</p> <ul style="list-style-type: none"> · Draft Blank drawings · Draft Substrate drawings · Draft Material specifications · Draft Polishing specifications · Draft Coating specifications <p>These deliverables must be supported by documented analyses of diffractive loss, scattering loss, internal</p> <p>modes/frequencies and acceptable wavefront distortion limits (figure and micro-roughness) to demonstrate (via</p> <p>analysis) that the requirements have been met. These deliverables must also incorporate all system level defined, or</p> <p>interface derived, requirements.</p> <p>Since the selection for the test mass material (sapphire or fused silica) will not have been made, the deliverable</p> <p>specifications above must be provided for both materials/designs.</p>	
WBS Author	WBS Date
G. Billingsley	04/30/2001

Advanced LIGO - WBS Dict. Report

WBS No.	WBS Description
LIGO.4.06.3.2.2	Fixture/Handling Design
WBS Definition	
<p>The design for all of the fixtures and handling equipment to be used for transport, cleaning and measurement is covered under this WBS element. This includes a COC carrier design(s) for transport and storage and fixtures for holding and moving the COCs for the purpose of cleaning and inspection. The design should cover all substrate types including fused silica and sapphire test masses.</p> <p>This task does not include the design for fixtures or handling equipment used for metrology or for any processing steps used in the assembly process for the suspension subsystem. At the PDR a nearly complete set of draft drawings should be available for all of the fixtures. These fixtures will be used as part of the Pathfinder-II effort (see WBS 0.4.6.3.4).</p>	
WBS Author	WBS Date
G. Billingsley	12/04/2002

WBS No.	WBS Description
LIGO.4.06.3.2.3	Cleaning Process Design
WBS Definition	
<p>A cleaning process should be designed and documented in a set of draft cleaning specifications. The specifications must cover cleaning prior to bonding attachments (silicate bonding), cleaning in an optics lab with or without attachments after extended atmospheric exposure and in-situ cleaning of optics which have been integrated into a suspension assembly.</p>	
WBS Author	WBS Date
G. Billingsley	12/04/2002

Advanced LIGO - WBS Dict. Report

WBS No.	WBS Description
LIGO.4.06.3.2.4	Metrology Design

WBS Definition

The design of all measurement equipment needed to perform acceptance testing and characterization of the core optics are covered under this WBS element. This includes any handling equipment or fixtures which are specific to the metrology instruments. The metrology required includes:

- Interferometric surface and transmission figure measurement (post coating)
- Radius of curvature measurement
- Bulk and surface scatter measurement

Design information appropriate to a preliminary design should be generated under this WBS element.

WBS Author	WBS Date
G. Billingsley	12/04/2002

WBS No.	WBS Description
LIGO.4.06.3.2.5	Mechanical Tests Design

WBS Definition

Not Used.

WBS Author	WBS Date
T. Frey	04/30/2001

Advanced LIGO - WBS Dict. Report

WBS No.	WBS Description
LIGO.4.06.3.3	COC Final Design
WBS Definition	
<p>All design and development activities up to and including the COC Final Design Review (FDR) are covered under this</p>	
<p>WBS element (except for associated R&D covered under WBS elements 0.4.6.2 and long lead items</p>	
<p>The decision on whether to use sapphire or fused silica optics for the ITM and ETM will be made before the COC FDR.</p>	
<p>The principal deliverables for this WBS element are as follows:</p>	
<p>1) if required, a revised Design Requirements Document for Core Optics Components (COC)</p>	
<p>2) Final Design Document for Core Optics Components (COC)</p>	
<p>Completion of the FDR milestone marks the end of this WBS element. Preparation for , presentation of, and follow-up</p>	
<p>response to, the Conceptual Design Review (FDR) is also part of this WBS element.</p>	
WBS Author	WBS Date
T. Frey	04/30/2001

Advanced LIGO - WBS Dict. Report

WBS No.	WBS Description
LIGO.4.06.3.3.1	Optics Design
WBS Definition	
<p>The activities leading to a complete definition of the optical prescription for the core optics are covered under</p> <p>this WBS element. The deliverables of this WBS element are:</p> <ul style="list-style-type: none"> · Blank drawings · Substrate drawings · Material specifications · Polishing specifications · Coating specifications <p>These deliverables should be released, final documents. These deliverables must be supported by documented analyses</p> <p>of diffractive loss, scattering loss, internal modes/frequencies and acceptable wavefront distortion limits (figure</p> <p>and micro-roughness) to demonstrate (via analysis) that the requirements have been met. These deliverables must also</p> <p>incorporate all system level defined, or interface derived, requirements. Since the selection for the test mass material (sapphire or fused silica) will not have been made, the deliverable</p> <p>specifications above must be provided for both materials/designs.</p>	
WBS Author	WBS Date
T. Frey	04/30/2001

Advanced LIGO - WBS Dict. Report

WBS No.	WBS Description
LIGO.4.06.3.3.2	Fixture/Handling Design
WBS Definition	
<p>The final design for all of the fixtures and handling equipment to be used for transport, cleaning and measurement</p> <p>is covered under this WBS element. This includes a COC carrier design(s) for transport and storage and fixtures for</p> <p>holding and moving the COCs for the purpose of cleaning and inspection. However, this task does not include the</p> <p>design for fixtures or handling equipment used for metrology or for any processing steps used in the assembly</p> <p>process for the suspension subsystem.</p> <p>At the PDR a complete set of drawings, ready for fabrication, should be available for all of the fixtures. These</p> <p>fixtures will be used as part of the Pathfinder-II effort (see WBS 0.4.6.3.4).</p>	
WBS Author	WBS Date
T. Frey	04/30/2001

WBS No.	WBS Description
LIGO.4.06.3.3.3	Cleaning Process Design
WBS Definition	
<p>A cleaning process should be designed and documented in a set of released cleaning specifications. The</p> <p>specifications must cover cleaning prior to bonding attachments (silicate bonding), cleaning in an optics lab with or without attachments after extended atmospheric exposure and in-situ cleaning of optics which have been integrated into a suspension assembly.</p>	
WBS Author	WBS Date
G. Billingsley	12/05/2002

Advanced LIGO - WBS Dict. Report

WBS No.	WBS Description
LIGO.4.06.3.3.4	Metrology Design
WBS Definition	
<p>The final design of all measurement equipment needed to perform acceptance testing and characterization of the core</p> <p>optics are covered under this WBS element. This includes any handling equipment or fixtures which are specific to</p> <p>the metrology instruments. The metrology required includes:</p> <ul style="list-style-type: none"> · Interferometric surface and transmission figure measurement (post coating) · Birefringence measurement (bulk and coating) · Bulk absorption level and uniformity measurement · Scatter measurement · Radius of curvature measurement 	
WBS Author	WBS Date
G. Billingsley	04/30/2001

WBS No.	WBS Description
LIGO.4.06.3.3.5	Mechanical Tests Design
WBS Definition	
Not Used.	
WBS Author	WBS Date
G. Billingsley	04/30/2001

WBS No.	WBS Description
LIGO.4.06.4	COC Fabrication
WBS Definition	
<p>This is a top level WBS element. All elements below this WBS are for production of optics to be installed at the sites. Exception is 4.06.4.1, Pathfinder.</p>	
WBS Author	WBS Date
G. Billingsley	05/11/2001

Advanced LIGO - WBS Dict. Report

WBS No.	WBS Description
LIGO.4.06.4.1	Pathfinder
WBS Definition	
SMALL PATH FINDER (SPF)	
Provide optics at current state of the art to support high power testing at Gin Gin, UWA.	
LARGE PATH FINDER (LPF)	
In addition to serving as a summary WBS element for all COC fabrication (other than the fabrication associated with the R&D elements), the Pathfinder-II effort is also covered under this WBS element. The purpose of the Pathfinder-II program is to demonstrate the ability of industrial partners to achieve the requirements for:	
<ul style="list-style-type: none"> · Sapphire blanks: in the large sizes required for LIGO-II with required homogeneity and low bulk absorption at 1064 microns. Although sapphire material development is covered under WBS elements 04.6.2.2 and 04.6.2.4 these efforts are focused on small samples and enabling research to be able to attempt production of large blanks meeting LIGO-II requirements. The cost for the large scale blanks is to be covered under this WBS element, as a proof of capability and the first step in the Pathfinder program. · Sapphire polishing: The full scale blanks procured under this WBS element, will be polished to demonstrate the capability meet LIGO-II requirements on full scale optics. · Coating: on large diameter optics to equal or better than the LIGO-1 requirement for absorption in the high-reflectance coatings. The purpose of this WBS element is the qualification of a new coating vendor and possibly a new coating prescription (for lower absorption) at full scale size, whether on fused silica or sapphire. The small scale coating research (WBS element 04.6.2.1) is to define a suitable coating for sapphire substrates and a coating prescription for a lower absorption high reflectance coating on fused silica. The results of this small scale coating research are applied under this WBS element at full scale in a production facility. 	
WBS Author	WBS Date
G. Billingsley	05/11/2001

WBS No.	WBS Description
LIGO.4.06.4.2	Metrology Fabrication
WBS Definition	
The subcontracts and procurement for all metrology equipment and associated special purpose fixtures are covered under this WBS element. This also includes:	
<ul style="list-style-type: none"> · all shipping · consulting for subcontract oversight · trips to vendors for subcontract review · all QA or acceptance testing 	
WBS Author	WBS Date
G. Billingsley	04/30/2001

Advanced LIGO - WBS Dict. Report

WBS No.	WBS Description
LIGO.4.06.4.3	Substrate Blanks
WBS Definition	
<p>The subcontracts/procurement for all core optic blanks (including spares are covered under this WBS element. This dos not include the Pathfinder-II program, but does include:</p> <ul style="list-style-type: none"> · all shipping · consulting for subcontract oversight · trips to vendors for subcontract review · all QA or acceptance testing 	
WBS Author	WBS Date
G. Billingsley	04/30/2001

WBS No.	WBS Description
LIGO.4.06.4.4	Polishing
WBS Definition	
<p>The subcontracts/procurement for all core optic substrate polishing (including spares are covered under this WBS element. This dos not include the Pathfinder-II program, but does include:</p> <ul style="list-style-type: none"> · all shipping · consulting for subcontract oversight (if any) · trips to vendors for subcontract review · all QA or acceptance testing 	
WBS Author	WBS Date
G. Billingsley	04/30/2001

WBS No.	WBS Description
LIGO.4.06.4.5	Coating
WBS Definition	
<p>The subcontracts/procurement for all core optic coating (including spares are covered under this WBS element. This dos not include the Pathfinder-II program, but does include:</p> <ul style="list-style-type: none"> · all shipping · consulting for subcontract oversight (if any) · trips to vendors for subcontract review · all QA or acceptance testing 	
WBS Author	WBS Date
G. Billingsley	04/30/2001

Advanced LIGO - WBS Dict. Report

WBS No.	WBS Description
LIGO.4.06.4.6	Cleaning Process Equipment

WBS Definition
<p>The subcontracts and/or procurement for all cleaning equipment and associated special purpose fixtures are covered under this WBS element. This also includes:</p> <ul style="list-style-type: none"> · all shipping · consulting for subcontract oversight (if any) · trips to vendors for subcontract review · all QA or acceptance testing

WBS Author	WBS Date
G. Billingsley	04/30/2001

WBS No.	WBS Description
LIGO.4.06.4.7	Metrology Testing/Qualification

WBS Definition

WBS Author	WBS Date

WBS No.	WBS Description
LIGO.4.06.4.8	Fixture/Handling Fabrication

WBS Definition

WBS Author	WBS Date