LIGO-II Work Breakdown Structure (WBS) Dictionary

1 General Comments:

All research, development, design, construction, assembly and of the LIGO-II instrument are covered under this WBS structure, organized by subsystems.
The design is separated into three sequential phases:

- Requirements/Conceptual Design Phase (CD): The conceptual design and requirements task encompasses the development of a documented set of requirements (Design Requirements Document) in conjunction with the systems engineering group and the development of a documented conceptual design (Conceptual Design Document) which is responsive to the requirements. A project review of the design (Conceptual Design Review, CDR) is held at the end of this phase.
- Preliminary Design Phase (PD): The preliminary design task encompasses the development of a documented set of refined requirements (Design Requirements Document) in conjunction with the systems engineering group and the development of a documented preliminary design (Preliminary Design Document) which is responsive to the requirements. A project review of the design (Preliminary Design Review, PDR) is held at the end of this phase.
- Final Desgn Phase (FD): The final design task encompasses the development of a set of documentation which is sufficient to build the subsystem including an overall detailed design description (Final Design Document) which is responsive to the requirements. A project review of the design (Final Design Review, FDR) is held at the end of this phase. The final design documentation includes reports of supporting simulations, analyses, tests, as well as drawings, fabrication specifications, procurement plans, and assembly and installation procedures.

0 LIGO

Root WBS denotes the overall LIGO project.

0.4 LIGO-II Construction

All research, development, design, construction, assembly and of the LIGO-II instrument are covered under this WBS structure, organized by subsystems.
The installation of the LIGO-II instrument is also part of this WBS, but is handled as a separate WBS element, not prt of the subsystem WBS elements.

0.4.3Suspension (SUS)

All suspended optics assemblies for the interferometer are covered under this WBS element, including input optics (mode cleaner, mode matching telescope optics and relay optics), output optics (mode cleaner and relay optics) and core optics (Fabry-Perot cavity optics, power and signal recycling cavity optics). Other optics or electro-optics which may need to be suspended are part of the associated subsystem and are not part of this WBS element (e.g. a suspended reference cavity for the PSL subsystem is not part of this WBS element). There are a few different suspension designs required to meet performance requirements, space constraints and variation in the dimensions/geometry of the optics. Commonality of the design elements and components is a goal within the suspension effort.
This is a summary level WBS element only; no costs are allocated to this WBS element.

0.4.3.1 Subsystem Management

Technical management of the subsystem is covered in this WBS element. This is a level of effort task (the level may vary according to the development phase).

0.4.3.2 Suspension R&D

All research & development across the entire LIGO Science Collaboration (LSC) related to suspensions for LIGO-II are reported to, and coordinated by, the Suspension subsystem leader.
This is a summary level WBS element only; no costs are allocated to this WBS element.

0.4.3.2.1 Suspension R&D - Caltech Fiber/Optics Components

TBW

0.4.3.2.2 Suspension R&D – TNI

TBW

0.4.3.2.3 Suspension R&D – GEO

TBW

0.4.3.2.4 Suspension R&D – Stanford

TBW

0.4.3.2.5 Suspension R&D – Syracuse

TBW

0.4.3.3 Suspension Design

All suspension design activities are covered under the following WBS elements.
This is a summary level WBS element only; no costs are allocated to this WBS element.

0.4.3.3.1 Conceptual Design/Requirements

All suspension design work and costs associated with the Conceptual Design Phase are allocated to this WBS element. The principal deliverables from this element are the Design Requirements Document and the Conceptual Design Document. This WBS element is completed when a successful Design Requirements Review (DRR) has been held and the Preliminary Design Phase is initiated.

0.4.3.3.2 Preliminary Design

All suspension design work and costs associated with the Preliminary Design Phase are allocated to this WBS element. The principal deliverables from this element are the revised Design Requirements Document (if required), the Preliminary Design Document a prototype(s) and associated prototype test results. This WBS element is completed when a successful Preliminary Design Review (PDR) has been held and the Final Design Phase is initiated.
Activities and associated costs, which cannot be allocated to the elements below this level, may be defined at this level, such as: preparation of the design review documentation and conducting the design review.

0.4.3.3.2.1 Ribbon/Fiber Process Design

The engineering and process design for the reliable fabrication of silica fibers or ribbons needed in the suspension are covered in this WBS element. The principal deliverables of this WBS element are a preliminary process specification, preliminary ribbon or fiber prototypes and associated testing of their strength, uniformity and suitability for the suspension system.

0.4.3.3.2.2 Optic/Ribbon Attachment Design

Move this WBS element to the Core Optics Component (COC) structure.

0.4.3.3.2.3 Sensor Design

The design activities for the local damping sensors of the suspensions are allocated to this WBS element. The principal deliverables of this WBS element are a preliminary design description including physical drawings and electronic circuit schematics of the read-out/interface, a tested prototype and test report.

0.4.3.3.2.4 Actuation Design

The design activities for the suspension actuators are allocated to this WBS element. The actuators include both magnetic voice coil actuators and electrostatic actuators. (The photon actuator is not part of this WBS element.) The principal deliverables of this WBS element are a preliminary design description including physical drawings and electronic schematics of the drive/interface circuit, a tested prototype and test report.

0.4.3.3.2.5 BSC Suspension Design

The suspensions for optics housed in the BSC chambers (attached to an interface with the SEI subsystem at their tops) are covered under this WBS element.
This is a summary level WBS element only; no costs are allocated to this WBS element.

0.4.3.3.2.5.1 System Design/Simulation

Overall design trade-offs and simulations of the integrated control and system dynamics of the BSC suspension preliminary design are covered in this WBS element. The deliverable from this element is a documented simulation model and a report on comparisons of the simulation of the performance of the preliminary design against requirements and against prototype testing.

0.4.3.3.2.5.2 Mechanical Design

All activities associated with the preliminary mechanical design of the BSC suspension are covered in this WBS element (except or those associated with other preliminary design phase elements such as the sensor design, actuator design and the assembly and installation tooling design). This relates principally to the design of the structure(s) used to interface to the SEI system, suspend the multiple pendulum, mount the sensors and actuators and cage or 'safe' the suspended masses. The principal deliverables of this WBS element are a preliminary design description including physical drawings and schematics, a tested prototype and test report.

0.4.3.3.2.5.3 Control System Hardware & Software Design

All activities associated with the preliminary control system design of the BSC suspension are covered in this WBS element. The principal deliverables of this WBS element are a preliminary design description including a system block diagram, a control block diagram, a hardware layout drawing, a software development plan, electronic circuit schematics of any required custom control and interface electronics, a tested prototype and test report.

0.4.3.3.2.5.4 Assembly Procedure & Tooling Design

All activities associated with the design and definition of a procedure for the physical assembly and test of the BSC suspension are covered in this WBS element. The principal deliverables of this WBS element are a preliminary assembly specification, drawings of assembly tools and fixtures, prototype assembly tools and fixtures and a report on an assembly trial.

0.4.3.3.2.5.5 Installation Procedure & Tooling Design

All activities associated with the design and definition of a procedure for the physical installation and in-situ test of the BSC suspension are covered in this WBS element. The principal deliverables of this WBS element are a preliminary installation specification, drawings of installation tools and fixtures.

0.4.3.3.2.5.6 Prototype Fabrication

Activities and costs associated with the fabrication of integrated BSC suspension prototypes are covered in this WBS element. Prototype fabrication of components (e.g. sensors, actuators, etc.) are covered under other WBS elements; This WBS element is strictly for the development of two complete integrated BSC suspensions that are tested stand-alone. One prototype is to be used in air principally for assembly and installation testing. The other prototype is to be used in a vacuum chamber for use in control system testing. The deliverables for this WBS element are two complete BSC prototype

suspensions, one set of assembly tools and a susupension test stand including limited data acquisition capability to support testing.

0.4.3.3.2.5.7 Prototype Testing

Activities and costs associated with the testing of integrated BSC suspension prototypes are covered in this WBS element. Prototype testing of components (e.g. sensors, actuators, etc.) are covered under other WBS elements; This WBS element is strictly for the testing of the two complete integrated BSC suspensions (from 0.4.3.3.2.5.6). A test report on the assembly, installation, fit, function and (to the extent possible) performance of the suspensions is a deliverable of this WBS element

0.4.3.3.2.6 HAM Suspension Design

0.4.3.3.2.6.1 System Design/Simulation

0.4.3.3.2.6.2 Mechanical Design

0.4.3.3.2.6.3 Control System Hardware & Software Design

0.4.3.3.2.6.4 Assembly Procedure & Tooling Design

0.4.3.3.2.6.5 Installation Procedure & Tooling Design

0.4.3.3.2.6.6 Prototype Fabrication

0.4.3.3.2.6.7 Prototype Testing

0.4.3.3.3 Final Design

0.4.3.3.3.1 Ribbon Process Design

0.4.3.3.3.2 Optic/Ribbon Attachment Design

0.4.3.3.3.3 Sensor Design

0.4.3.3.3.4 Actuation Design

0.4.3.3.3.5 BSC Suspension Design

0.4.3.3.3.5.1 System Design/Simulation

0.4.3.3.3.5.2 Mechanical Design

0.4.3.3.3.5.3 Control System Hardware & Software Design

0.4.3.3.3.5.4 Assembly/Installation Design

0.4.3.3.3.5.5 Prototype Fabrication

Activities and costs associated with the fabrication of integrated BSC suspension prototypes are covered in this WBS element. Prototype fabrication of components (e.g. sensors, actuators, etc.) are covered under other WBS elements; This WBS element is strictly for the development of complete integrated BSC suspensions that are tested in the LASTI system at MIT. Two complete BSC prototype suspensions including one set of assembly and installation tools and fixtures are deliverables of this WBS element.

0.4.3.3.3.5.6 Prototype Testing

Activities and costs associated with the testing of integrated BSC suspension prototypes are covered in this WBS element. Prototype testing of components (e.g. sensors, actuators, etc.) are covered under other WBS elements; This WBS element is strictly for the testing of complete integrated BSC suspensions that are tested in the LASTI system at

MIT. A test report on the assembly, installation, fit, function and (to the extent possible) performance of the suspensions is a deliverable of this WBS element. While labor and infrastructure support will be provided by the LASTI system, all labor for the assembly, installation and test of the suspension prototypes should be allocated to this WBS element.

0.4.3.3.3.6 HAM Suspension Design

0.4.3.3.3.6.1 System Design/Simulation

0.4.3.3.3.6.2 Mechanical Design

0.4.3.3.3.6.3 Control System Hardware & Software Design

0.4.3.3.3.6.4 Assembly/Installation Design

0.4.3.3.3.6.5 Prototype Fabrication

0.4.3.3.3.6.6 Prototype Testing

0.4.3.4 Fabrication (LOS & SOS)

0.4.3.4.1 Fused Silica Mass Fabrication

0.4.3.4.1.1 Fused Silica Blanks

0.4.3.4.1.2 Fused Silica Polishing

0.4.3.4.2 Tooling Fabrication

0.4.3.4.2.1 Assembly Tooling Fabrication

0.4.3.4.2.2 Installation Tooling Fabrication

0.4.3.4.3 BSC Suspension Fabrication

0.4.3.4.3.1 Mechanical Fabrication

0.4.3.4.3.2 Electronics Fabrication

0.4.3.4.3.3 Software Coding

0.4.3.4.3.4 First Article Testing

0.4.3.4.4 HAM Suspension Fabrication

0.4.3.4.4.1 Mechanical Fabrication

0.4.3.4.4.2 Electronics Fabrication

0.4.3.4.4.3 Software Coding

0.4.3.4.4.4 First Article Testing

0.4.3.4.5 Production Assembly & Test

0.4.3.4.5.1 SUS/BSC Test Stands

0.4.3.4.5.2 SUS/HAM Test Stands

0.4.3.4.5.3 BSC Suspension Controllers

0.4.3.4.5.4 HAM Suspension Controllers

0.4.3.4.5.5 BSC Suspensions

0.4.3.4.5.6 HAM Suspensions