

Outline

Systems Engineering and Integration

Albert Lazzarini

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- Accomplishments
 - » Interfaces/Integration
 - » Plans
 - » Modeling
 - » Trade Studies/Analyses
- Status of Activities
 - » Interfaces/Integration
 - » Plans
 - » Modeling
 - » Trade Studies/Analyses
- Action on Recommendations from Fall NSF Review



LIGO Systems Engineering and Integration Accomplishments

LIGO Systems Engineering and Integration Accomplishments

- Integration/Interfaces
 - » Issued major interface definition and control documents (ICDs)
 - » Regular Integration Meetings (weekly) and Science and Integration Meetings (Quarterly) with project-wide participation
 - Facilities Monitoring & Controls System (FMCS) requirements (CC)
 - ▣ - Modularity/extensibility
 - ▣ - Remote control/data access/logging of facilities state vector
 - Variable frequency motor drives (Facility HVAC; noise issue)
 - BT Termination loads (Potential BT failure issue)
 - LVEA/VEA slab thickness resolved (Science requirement for Detector)
 - Site alignment requirements (BT/VE alignment)
 - » Integrated Layout Drawings developed & under config. control

- System Plans
 - » Draft Configuration Management Plan under internal review
 - » Draft EMI/EMC Plan draft released
 - W. Parker, consultant
 - » Reliability Plan nearing completion
 - M. Krasich, JPL
- Modeling
 - » AVS-based dynamic interferometer response model
 - » Major LIGO noise sources developed as AVS modules
 - » LIGO FFT code (diffractive propagation model of LIGO interferometer) parallelized
 - Center for Advanced Computing Research (Caltech: CACR)
 - Paragon SC: 50x -> 100x speed-up over Sparc 20



Accomplishments

- Analyses & Trade Studies
 - » Improved estimates of the BT bellows fatigue life
 - Advisability of permanent deflection testing
 - » Selected the BT baffle material
 - Performance requirements defined
 - » Resolved vacuum tube and gate valve aperture trade related to thermal and laser baffling considerations
 - » Worked with the facilities group in the definition of the logistics of availability of portable pumps during BT installation.
 - » Finalized BT pump-port - BTE alignment for use of VE pump carts
 - » Developed assessment of alignment requirements
 - Visit to SLAC
 - Quantification of BT alignment error build-up and LIGO requirements



Status

- Integration/Interfaces
 - » Interface Control Documents (ICDs)
 - Concurrent design of buildings, Vacuum Equipment and Detector make the interfaces difficult to finalize early
 - We have evolved to an incremental issue/interface resolution approach for timeliness (iterative approach)
 - ICD captures final concurrence
 - Pending changes or TBDs to be resolved
 - ✘ Final VE electrical power requirements [VE-CC]
 - ✘ LN2 tank bolt-hole locations/specs [VE-CC]
 - ✘ BT portal details [BT-CC]
 - ✘ Detector cable raceway locations [DET-CC]
 - ✘ Service support of VE portable pumps used during BT installation along BT [BT-VE; VE-CC]
 - ✘ Various updates reflecting revised (mutually agreed upon) designs



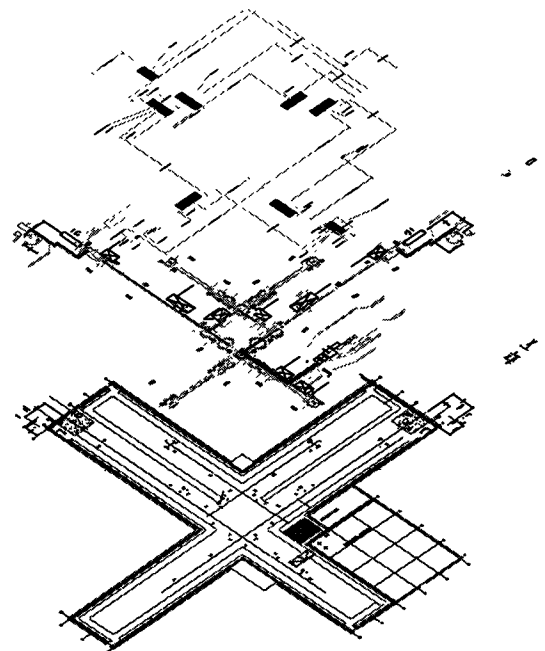
STATUS OF ICDs

INTERFACE	SUMMARY STATUS	Primary Resp.	COMMENTS
VE-CC	ISSUED 10/26/05 3rd Draft in Revision Project final 4/22	Coyne	VE power requirements to be revised based on final design Revised VE layout in the mid- and end-stations Include interior survey reference monuments for alignment Finalized coolant and exhaust interface details
BT-CC	ISSUED 10/23/05 SIGNED 11/13 Revision Projected 4/15	Lazzarini	Revised BT installation power requirements Revised BT module dimensions in LA Correction to High-Y vault locations Change preliminary termination slab loads to final
Detector-CC	ISSUED 4/2/06 Precameal Release 9/12+ Revision Projected 6/3	Coyne	Include interior survey reference monuments for alignment Define data/software interface between FMCS and CDS
Detector-VE	ISSUED 4/5/06 Precameal Release 9/29+ Revision Projected 5/24	Zucker, Coyne	Incorporate CDS/COMS-VE control interface details Define ACS slay-clear zones Define CDS cable tray runs after VE piping/conduit runs stabilize
BT - VE	ISSUED 12/14/05 CBI Pump Port ICD Rev'd 2/13/06 2nd draft in Revision Release Projected 4/25	Lazzarini CBI/PSI	Incorporate valve self-support interface details Incorporate pump port and gate valve flange/interface details Include pump port hardware and BT pump layout constraints at SEE and termination foundations
BT - Detector	SYNOPSIS SPEC. TO DETECTOR Draft by 6/1, Final by 7/1	Conley, Althouse	Augment the CBI pump port hardware ICD to define interfaces for PEM



Status

LVEA Integrated Layout Drawing Example



Status

- Electromagnetic Interference (EMI) Control Plan
 - » Draft of the control plan under internal review
 - EMI/EMC Consultant/Specialist (W. Parker, EE)
 - Technical direction of Integration Group & working with Detector/CDS to develop design policies
 - » Commissioned a survey of Tri-Cities area, WA electromagnetic wave spectrum to assess environment:
 - Radio stations
 - Television stations
 - Microwave links
 - » Design policies/strategies being defined with CDS
 - Ground plane (“island”) grounding strategy for the CDS rack clusters
 - Fiber optics for communication and controls in between rack clusters and buildings
 - Separation/isolation between facility and technical power sources by two stages of transformation
 - » Possible EMI/EMC tests are under consideration



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Status

- Reliability Program Plan
 - » Plan is approximately 80% complete
 - Being developed via JPL engineering support
 - M. Krasich, Reliability Engineer
 - » Evaluation of LIGO systems’ availability requirements
 - » Transformation of availability requirements into mean time between failures (MTBF) and mean down time (MDT) allocation
 - » Reliability analyses and trade-offs to ensure that LIGO reliability requirements can be met. Analyses and estimates to be performed at several stages:
 - Preliminary or early inputs to design reviews (DRR)
 - Full scale design and development (FDR)
 - Integration, test & evaluation
 - » Maintainability analyses to determine:
 - System and subsystem mean time to repair (MTTR) as one of the factors in MDT
 - Scheduled system routine and preventive maintenance, i. e. replacement of parts subject to wear out or limited life



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Status

- Configuration Management Plan
 - » Draft Configuration Management Plan distributed for internal review
 - Technical Configuration Manager appointed to implement processes and standards described in Plan.
 - Change Control Board (CCB) reviews proposed changes which affect safety, cost, schedule or technical performance baselines.
 - Technical Review Board (same membership as the CCB) reviews technical proposals and proposed changes which affect broad project policy not confined to specific CCB action.
 - » Integration Group has defined naming conventions so that a uniform reference designation system can be established.
 - » Integration Group is establishing a Hardware Configuration Item (HWCI) list which will describe the specification/drawing tree for each individual hardware component.
 - » Electronic access to documents & drawings in the Document Control Center is being developed



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Status

- Modeling
 - » Transition from AVS5 to AVS/Express
 - AVS/Express is a visual, objected oriented development environment
 - More powerful and more easily customized
 - » Completion of the noise model
 - Modeling remaining noise contributions:
 - ☒ Residual gas noise,
 - ☒ Amplitude and frequency noise in the laser,
 - » Inclusion of control system in interferometer (IFO) simulation
 - Simple control based on in-lock state model
 - » Integration of the IFO and noise model
 - Completion of the V.1 of End-to-End model
 - Target - November 96



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Status

- Modeling
 - » GUI for parallelized FFT program
 - Easy to setup data for the program
 - Efficient communication between SS20 front-end (at LIGO) and Paragon (at CACR)
 - » Development of the time domain IFO model
 - Large angle misalignment and arbitrary size of displacement
 - Inclusion in the End-to-End model
 - » Modeling Software Design Standard documentation
 - In progress; draft released for internal review



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LIGO Systems Engineering and Integration Actions on Recommendations from Fall 1995 Review

- Proceed with baffle prototypes & design
(Pg. 18, Review Report; Detector)
 - » Baffle prototype completed
 - » Mechanical design finalized;
 - normal modes analysis-> substrate thickness
 - attachment/installation concept
 - » Procurement of fabricated baffles in place



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Status

- Trade studies & analyses
 - » Alignment tolerances for BT installation -- near completion
 - » Thermal radiation transport in VE manifolds (LN₂ trap heat loads vs. optical baffling requirements) -- VE/ chamber baffling activity
 - » Thermal analysis of BT during operations -- partly completed
 - Diurnal temperature excursions
 - Deflection & clear aperture requirements



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LIGO Systems Engineering and Integration Actions on Recommendations from Fall 1995 Review

- Vacuum and optical compatibility of glazing
(Pg. 18, Review Report; Detector)
 - » Acceptable vacuum outgassing properties demonstrated
 - Residual H₂ outgassing rates after bakeout @ 150C < 10⁻¹² t-l/cm²/s
 - Surface HC contamination < 0.1 monolayer (XPS measurements @ MIT)
 - » Optical qualities determined
 - Glints < backscatter
 - Backscatter: 2-3 x 10⁻³ sr⁻¹
 - Reflectivity: < 0.10 (averaged over S & P polarizations)
 - » Coating robustness
 - substrate thickness increased (1 mm)
 - glaze thickness increased (0.1 - 0.2 mm).



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LIGO Systems Engineering and Integration Actions on Recommendations from Fall 1995 Review

- Chamber baffling needs to be included in analysis & design
(Pg. 18, Review Report; Detector)
 - » To be performed under Core Optics Support task
 - » Design of local baffles not as critical (i.e., irreversible) as BT baffling
- Develop a mock-up of the BT/BTE/VE systems
(Pg. 20, Review Report; Integration)
 - » Funds for relocation of CB&I QTR BT sections allocated
 - » University has provided space in synchrotron building
 - » BT section is now at Caltech
 - » BTE mock-up design & fabrication proceeding
 - » Two VE mock-up options being considered:
 - Fabricate temporary wooden structure of a BSC
 - Negotiate with PSI for (temporary) delivery/use of BSC 1st article prototype



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LIGO Systems Engineering and Integration Actions on Recommendations from Fall 1995 Review

- Complete and Issue major ICDs
(Pg. 20, Review Report; Integration)
 - » Distributed effort among Integration Group staff
 - » Five major ICDs completed
 - 1 Officially under configuration control (BT-CC)
 - 2 De-facto under control (BT-VE; VE-CC)
 - ✦ Revisions pending due to refined interface definitions
 - 2 Released for internal (draft) review (DET-VE; DET-CC)



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LIGO Systems Engineering and Integration Planned Activities

- Issue system plans:
 - » EM/EMC Plan
 - » Reliability Plan
 - » Configuration Management Plan
- Initiate 3-D integrated VE chamber layouts with Detector Group
- Allocation of MTBF/MDT at subsystem levels (within detector and facilities)
- Data formats/dynamic ranges/rates design freeze
 - » VIRGO/LIGO topical meeting
- Refine integration plan beyond 1995 Operations Proposal
- Conduct internal system-level configuration audit after facilities Final Design Reviews (FDRs) are complete



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