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WBS	Description	Dictionary
1	12 GeV Upgrade to CEBAF (including non-DOE scope)	CEBAF Upgrade to 12 GeV, New Hall D, Halls A,B,C Upgraded to 11 GeV to include non-DOE scope.
1.0	CDR/ACD	Conceptual and Advanced Design for 12 GeV Upgrade.
1.1	R&D	Research & Development to develop design solutions that meet performance goals while optimizing cost and schedule.
1.1.1	R&D Accelerator Systems	R&D for accelerator systems
1.1.1.1	R&D Accel Systems Cryomodules	Optimization and testing of cryomodule components.
1.1.1.2	R&D Accel Systems Power Systems	New LLRF Development for Cavity gradient, phase and tuning control.
1.1.1.3	R&D Accel Systems Cryogenics	Not Used.
1.1.1.4	R&D Accel Systems Beam Transport	Validation of magnet models.
1.1.1.5	R&D Accel Systems Extraction	Not Used.
1.1.1.6	R&D Accel Systems Instrumentation, Controls, and Safety Systems	Not Used.
1.1.2	R&D Hall A	R&D for Hall A
1.1.2.1	R&D Hall A Magnet	R&D to conduct a feasibility study for the combined function magnet of the Medium Acceptance Device spectrometer. This spectrometer was later de-scoped.
1.1.2.2	R&D Hall A Detector	Not Used.
1.1.2.3	R&D Hall A Computing	Not Used.
1.1.2.4	R&D Hall A Electronics	Not Used.
1.1.2.5	R&D Hall A Beamline	Not Used.
1.1.2.6	R&D Hall A Infrastructure	Not Used.
1.1.3	R&D Hall B	R&D of the CLAS12 in Hall B
1.1.3.1	R&D Hall B Torus Magnet	Not Used.
1.1.3.2	R&D Hall B Detector	SVT, Preshower EC, HTCC light-weight mirrors, Drift Chambers, Central TOF and Forward TOF.
1.1.3.3	R&D Hall B Computing	Not Used.

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1.1.3.4	R&D Hall B Electronics	Not Used.
1.1.3.5	R&D Hall B Beamline	Beamline Shielding
1.1.3.6	R&D Hall B Infrastructure	Not Used.
1.1.4	R&D Hall C	R&D for Hall C
1.1.4.1	R&D Hall C Magnet	Feasibility study of design options for 1st quadruple, build of test device to measure radiation heat at position of Horizontal Bend (HB) magnet, design and build of cross section model of HB magnet coil to design and test cooling system, and measurement of SC cable.
1.1.4.2	R&D Hall C Detector	Prototype quartz detector to verify trigger design, and optimization of calorimeter configuration.
1.1.4.3	R&D Hall C Computing	Not Used.
1.1.4.4	R&D Hall C Electronics	Not Used.
1.1.4.5	R&D Hall C Beamline	Not Used.
1.1.4.6	R&D Hall C Infrastructure	Not Used.
1.1.5	R &D Hall D	R&D for Hall D
1.1.5.1	R &D Hall D Magnet	Not Used.
1.1.5.2	R &D Hall D Detector	Prototypes of tracking chambers, fiber studies for barrel cal, UPV prototypes, and light collection in Cerenkov.
1.1.5.3	R &D Hall D Computing	Assess upgrade capabilities of computing systems for Hall D rate requirements.
1.1.5.4	R &D Hall D Electronics	Develop pipeline electronics, clock distribution needed for Hall D DAQ and Trigger.
1.1.5.5	R &D Hall D Beamline	Identify methods for production and monitoring of coherent bremstralung beams.
1.1.5.6	R &D Hall D Infrastructure	Not Used.
1.1.5.7	R &D Hall D Cryogenics	Not Used.
1.1.6	R&D Civil	R&D to support the design of the conventional facilities for the 12 GeV CEBAF Upgrade.
1.1.6.1	R&D Civil Hall D	Design and develop a mock-up to simulate the natural convection air conditioning system proposed for the Arc Tunnel air-conditioning.

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WBS	Description	Dictionary
1.1.7	R&D Project Management	R&D Project Management
1.2	PED	Project Engineering and Design for 12 GeV Upgrade
1.2.1	PED Accelerator Systems	Engineering and design of all Accelerator Systems.
1.2.1.1	PED Accel Systems Cryomodules	Project Engineering and Design for Cryomodules.
1.2.1.1.1	PED Accel Systems Cavity String Assembly	Work required for the completion of the 8-cavity string design and procurement documentation package.
1.2.1.1.1.1	PED Accel Systems Cavity String Assembly Cavities	Work required for the completion of the 7 cell cavity design and procurement documentation package. The cavity is considered all components that are welded together to from a 7 cell cavity Items that are bolted on are excluded.
1.2.1.1.1.2	PED Accel Systems Cavity String Assembly Niobium	Work required for the completion of the Niobium and Niobium Alloys specifications and procurement documentation packages. This includes all required RRR Niobium, Reactor Grade Niobium, and Niobium Titanium Alloy.
1.2.1.1.1.3	PED Accel Systems Cavity String Assembly Fundamental Power Coupler	Work required for the completion of the Fundamental Power Coupler design and procurement documentation package. The FPC includes the warm to cold waveguide, warm fro window, and all interfaces to these components such as flanges and thermal intercepts.
1.2.1.1.1.4	PED Accel Systems Cavity String Assembly Misc Cavity String Components	Work required for the completion of the Miscellaneous Cavity String Components design and procurement documentation package. Components including seals, clamps, hardware, and vacuum valves.
1.2.1.1.1.5	PED Accel Systems Cavity String Assembly HOM/Field Probes	Work required for the completion of the HOM coupler probe and cavity field probe design and procurement documentation package. This includes the electrical feedthroughs and the probe tips.
1.2.1.1.1.6	PED Accel Systems Cavity String Assembly Helium Vessels	Work required for the completion of the Helium Vessel design and procurement documentation package. This includes the Stainless Steel helium vessels, stiffening components, and transitions to the supply and return headers.
1.2.1.1.2	PED Accel Systems Space Frame Assembly	Work required for the completion of the Space Frame Assembly design and procurement documentation package. The space frame assembly includes: headers, tuners, magnetic shields, and thermal shields.
1.2.1.1.2.1	PED Accel Systems Space Frame Assembly Tuner Assembly	Work required for the completion of the Tuner Assembly design and procurement documentation package. The tune assembly includes the mechanism, hardware, actuators, and thermal intercepts.
1.2.1.1.2.2	PED Accel Systems Space Frame Assembly Header Assembly Supply and Return	Work required for the completion of the Helium Supply and Return Header Assembly design and procurement documentation package. This includes the helium supply and return headers, the phase separator, liquid level probe assembly and miscellaneous connections to the supply and return.

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1.2.1.1.2.3	PED Accel Systems Space Frame Assembly Magnetic Shield Assembly	Work required for the completion of the Magnetic Shield Assembly design and procurement documentation package. This includes the cold and warm magnetic shielding.
1.2.1.1.2.4	PED Accel Systems Space Frame Assembly Thermal Shield Assembly, MLI Blankets 2&	Work required for the completion of the Thermal Shield Assembly design and procurement documentation package. This includes the copper thermal shield and mylar multiple layer insulation for the 2 and 50 K circuits.
1.2.1.1.2.5	PED Accel Systems Space Frame Assembly Seals & Miscellaneous Space Frame Components	Work required for the completion of the seals and miscellaneous space frame components design and procurement documentation package. This includes the wheel assemblies, tie downs, and associated hardware.
1.2.1.1.2.6	PED Accel Systems Space Frame Assembly Space Frame	Work required for the completion of the Space Frame structural support member design and procurement documentation package.
1.2.1.1.3	PED Accel Systems Cryomodule Assembly	Work required for the completion of the cryomodule assembly and procurement documentation packages include: alignment, vacuum tank, end can, beamline inside cryomodule, cables, feedthroughs, and HOM loads.
1.2.1.1.3.1	PED Accel Systems Cryomodule Assembly Alignment Fiducials	Work required for the completion of the Fiducials design and procurement documentation package. This includes all work required to coordinate and design for meeting final installed alignment specification.
1.2.1.1.3.2	PED Accel Systems Cryomodule Assembly Vacuum Tank Assembly	Work required for the completion of the Vacuum Tank design and procurement documentation package. The vacuum tank assembly includes the vacuum tank proper as well as vacuum port closures.
1.2.1.1.3.3	PED Accel Systems Cryomodule Assembly End Can Assembly	Work required for the completion of the End Cans design and procurement documentation package. Includes the supply and return end can assemblies and required bridging components (process piping, shielding, and heat strapping) for integration into the cryo.
1.2.1.1.3.4	PED Accel Systems Cryomodule Assembly Beam Line Assembly within CM	Work required for the completion of the Beamline within CM design and procurement documentation package. This includes the warm to cold beamline transition, pump drop, warm valves and ion pump.
1.2.1.1.3.5	PED Accel Systems Cryomodule Assembly Stands	Work required for the completion of the Stands design and procurement documentation package. This includes the saddles, floor plates, and miscellaneous hardware required to install the cryomodule in the accelerator tunnel.
1.2.1.1.3.6	PED Accel Systems Cryomodule Assembly Wiring Incl HOM & FP Cables	Work required for the completion of the Wiring procurement documentation package including instrumentation and cabling.
1.2.1.1.3.7	PED Accel Systems Cryomodule Assembly Feedthroughs Incl Warm/Cold HOM/FP	Work required for the completion of the HOM coupler and cavity field probe feedthroughs procurement documentation package. Includes all warm vacuum feedthroughs for instrumentation and cables.
1.2.1.1.3.8	PED Accel Systems Cryomodule Assembly HOM Loads	Work required for the completion of the HOM Loads design and procurement documentation package. Includes all installed termination components outside the vacuum feedthroughs.

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1.2.1.1.4	PED Accel Systems Installation & Assembly Tooling	Work required for the completion of the design and procurement documentation packages for the tooling needed for cryomodule assembly and installation.
1.2.1.1.5	PED Accel Systems Cryomodule Test Instrumentation & Interlocks	Work required for the completion of the test instrumentation design and procurement documentation packages.
1.2.1.2	PED Accel Systems Power Systems	PED Rollup of RF and Magnet System Equip and Installation.
1.2.1.2.1	PED Accel Systems RF	PED Rollup of HL & LL RF System Equip and Installation.
1.2.1.2.1.1	PED Accel Systems RF Power	PED Roll up for High Power RF Source: Design and Planning for 10 Zones of Equipment and Installation.
1.2.1.2.1.1.1	PED Accel Systems RF Power Klystrons	PED for 13 kW RF Power Sources: Develop Requirements and Specifications for RF Device Procurement.
1.2.1.2.1.1.2	PED Accel Systems RF Power DC Power	PED for RF System: 10 HV DC PS and 10 High Power Amplifiers assemblies for the RF Power Sources.
1.2.1.2.1.1.3	PED Accel Systems RF Power Waveguide Components	PED for RF System Waveguide Components: Circulators, Couplers, and Waveguide plumbing for 80 RF cavities.
1.2.1.2.1.2	PED Accel Low Level RF System Control	PED Roll up for Low Level RF System: Design and Planning for 10 Zones of Equipment and Installation.
1.2.1.2.1.2.1	PED Accel Systems Control Field Control (RF/DSP)	PED for LLRF control modules for gradient and phase control Develop control hardware and algorithms for 80 cavities.
1.2.1.2.1.2.2	PED Accel Systems Control Resonance Control & Interlocks	PED for Cavity tuning electronics and cavity interlocks: 80 stepping motor tuners, 80 Piezo electric tuners, 10 zones of RF system interlocks.
1.2.1.2.1.2.3	PED Accel Systems Control Packaging/Interface	PED for racks, cables, control power and equipment integration for 80 cavities (10 zones) of LLRF, tuners, interlocks and controls.
1.2.1.2.1.2.4	PED Accel Systems Control CPU & Software	PED: Design and development of low cost LLRF embedded IOC and communications for 10 zones of RF equipment.
1.2.1.2.1.2.5	PED Accel Systems Control Test Stand	PED for offline test stands for LLRF controls development, calibration and testing.
1.2.1.2.1.2.6	PED Accel Systems Control Master Oscillator	PED: Develop requirements for extended RF Maser Oscillator reference line distribution.
1.2.1.2.1.2.7	PED Accel Systems Control HPA Controls (included in DC Power 1.2.1.2.1.2)	PED: Design and development of interlocks and controls for 10 new zones of High Power RF amplifiers and high voltage PS.
1.2.1.2.1.3	PED Accel Systems Installation	Element De-scoped Activities included in other WBS categories.
1.2.1.2.1.4	PED Accel Systems System Operation	Element De-scoped Activities included in other WBS categories.

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1.2.1.2.2	PED Accel Systems Magnet Power	PED Roll up of all magnet power supply upgrades.
1.2.1.2.2.1	PED Accel Systems Magnet Power Box Supplies	PED for Magnet Power Supply System design and specification: Modifying existing Box PS for reuse, procuring new Box PS for Arcs, Extraction/Transport lines and septa magnets.
1.2.1.2.2.2	PED Accel Systems Magnet Power Shunts	PED for upgrade of existing shunt system. (Not Used. identified)
1.2.1.2.2.3	PED Accel Systems Magnet Power Trims	PED for Quad and Corrector Magnet PS: New 20 amp trims, re-use of existing 10 amp trims, racks and supporting controls hardware.
1.2.1.2.2.4	PED Accel Systems Magnet Power Installation	PED Installation planning for all Magnet Power Supplies: Trims and Box PS, including cable, power and LCW installation requirements.
1.2.1.3	PED Accel Systems Cryogenics	Engineering and design and document development for cryogenics systems.
1.2.1.3.1	PED Accel Systems Cryogenics Accelerator	Engineering and design and document development for accelerator cryogenics upgrade.
1.2.1.3.1.1	PED Accel Systems Cryogenics Accelerator CHL Building Layout and Utilities Req	Existing and New CHL building detail requirements, equipment layout, utility schedules.
1.2.1.3.1.2	PED Accel Systems Cryogenics Accelerator CHL System P&ID Development	Process and Instrumentation Diagram Development for the Cryogenic Equipment Subsystems.
1.2.1.3.1.3	PED Accel Systems Cryogenics Accelerator CHL Warm Helium Compressors	Equipment specification and design criteria for new CHL 1st and 2nd stage warm helium compressors.
1.2.1.3.1.4	PED Accel Systems Cryogenics Accelerator CHL Cold Boxes	Equipment Specification and Design Criteria for the new CHL 4K cold boxes.
1.2.1.3.1.5	PED Accel Systems Cryogenics Accelerator CHL Oil Removal System	Equipment Fabrication Design and material specification for the Final Oil Removal Equipment Assembly.
1.2.1.3.1.6	PED Accel Systems Cryogenics Accelerator CHL Gas Management Rack	Engineering Design and Fabrication Documentation generation for the gas management valve rack assembly.
1.2.1.3.1.7	PED Accel Systems Cryogenics Accelerator CHL System Instrumentation and Controls	Engineering Design and material specification for the fabrication assembly of the new CHL instrumentation and control racks, programming, and system controls.
1.2.1.3.1.8	PED Accel Systems Cryogenics Accelerator CHL Instrument Air System	Additional Instrument Air System to support new CHL control valve operations.
1.2.1.3.1.9	PED Accel Systems Cryogenics Accelerator Motor Control Centers	480V and 4160V Motor Control Center Lineup Specification for purchase.
1.2.1.3.1.10	PED Accel Systems Cryogenics Accelerator CHL Installation Design	Electrical, Mechanical, and Controls Installation Design Package generation for field installation construction phase.

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1.2.1.3.1.11	PED Accel Systems Cryogenics Accelerator CHL Commissioning	Startup and Performance Testing of Installed new CHL refrigerator system.
1.2.1.3.1.12	PED Accel Systems Cryogenics Accelerator Linac Transfer Line	Completion of transfer line and bayonet assemblies, u-tubes for linac spare cryomodule slots.
1.2.1.3.2	PED Accel Systems Cryogenics Hall D	Engineering and design and document development for cryogenics systems.
1.2.1.3.2.1	PED Accel Systems Cryogenics CHL-Hall D Transfer Line	Not Used.
1.2.1.3.2.2	PED Accel Systems Cryogenics Hall D Cold Box	Inspect Hall D refrigerator currently in JLab Storage.
1.2.1.3.2.3	PED Accel Systems Cryogenics Hall D Distribution System	Engineer and Design Hall D Refrigerator Building helium, instrument air, cooling water, and utility piping.
1.2.1.3.2.4	PED Accel Systems Cryogenics Hall D Instruments and Controls	Engineer and Design Hall D Refrigerator instrumentation and process control system inclusive of control racks, computer controls, and instrument assemblies.
1.2.1.3.2.5	PED Accel Systems Cryogenics Hall D U-Tubes	Engineer and Design Hall D Refrigerator to Hall D transfer line interconnecting u-tubes fabrication documentation.
1.2.1.3.2.6	PED Accel Systems Cryogenics Hall D Field Installation	Not Used.
1.2.1.3.2.7	PED Accel Systems Cryogenics Hall D Commissioning	Not Used.
1.2.1.4	PED Accel Systems Beam Transport	E&D phase of upgrading beam transport system for accelerator.
1.2.1.4.1	PED Accel Systems Beam Transport Spreaders & Recombiners	E&D for reworking the 5 CEBAF Spreaders & Recombiners.
1.2.1.4.1.1	PED Accel Systems Beam Transport Spreaders & Recombiners Dipoles	Management of 1.2.1.4.1; misc cost and Tech labor; E&D: Design of all new and modified dipoles for the Spreaders and Recombiners.
1.2.1.4.1.2	PED Accel Systems Beam Transport Spreaders & Recombiners Quadrupoles	Not Used.
1.2.1.4.1.3	PED Accel Systems Beam Transport Spreaders & Recombiners Correctors	Not Used.
1.2.1.4.1.4	PED Accel Systems Beam Transport Spreaders & Recombiners Stands	E&D for overall layout of the five Spreaders and Recombiners Includes new and modified stands.
1.2.1.4.1.5	PED Accel Systems Beam Transport Spreaders & Recombiners Girders	Not Used.
1.2.1.4.1.6	PED Accel Systems Beam Transport Spreaders & Recombiners Vacuum	E&D for all dipole chambers, individual designs and overall layout.
1.2.1.4.1.7	PED Accel Systems Beam Transport Spreaders & Recombiners Installation	Not Used.
1.2.1.4.2	PED Accel Systems Beam Transports Existing Arcs (1-9, A, B, & C)	E&D costs for reworking the CEBAF Arcs and Hall A, B, & C Transport.

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1.2.1.4.2.1	PED Accel Systems Beam Transports Existing Arcs (1-9, A, B, & C) Dipoles	Management 1.2.1.4.2; E&D U channel and support for BE, BB, BA Magnets.
1.2.1.4.2.2	PED Accel Systems Beam Transports Existing Arcs (1-9, A, B, & C) Quadrupoles	Not Used.
1.2.1.4.2.3	PED Accel Systems Beam Transports Existing Arcs (1-9, A, B, & C) Correctors	Not Used.
1.2.1.4.2.4	PED Accel Systems Beam Transports Existing Arcs (1-9, A, B, & C) Stands & Girders	Layout and modification for the Hall B line. New girders, for existing Arcs and spreaders & recombiners.
1.2.1.4.2.5	Not used	Not Used.
1.2.1.4.2.6	PED Accel Systems Beam Transports Existing Arcs (1-9, A, B, & C) Vacuum	Not Used.
1.2.1.4.2.7	PED Accel Systems Beam Transports Existing Arcs (1-9, A, B, & C) Installation	Not Used.
1.2.1.4.3	PED Accel Systems Beam Transport Linacs	E&D costs for accommodating 10 new high gradient cryomodules.
1.2.1.4.3.1	PED Accel Systems Beam Transport Linacs Quadrupoles	Not Used.
1.2.1.4.3.2	PED Accel Systems Beam Transport Linacs Correctors	E&D of new correctors for LINACS.
1.2.1.4.3.3	PED Accel Systems Beam Transport Linacs Stands & Girders	Installation drawings and layout for new linac girders. Final design of new linac girders.
1.2.1.4.3.4	Not used	Not Used.
1.2.1.4.3.5	PED Accel Systems Beam Transport Linacs Vacuum	Not Used.
1.2.1.4.3.6	PED Accel Systems Beam Transport Linacs Installation	Not Used.
1.2.1.4.4	PED Accel Systems Beam Transport Injector & Re-injection	E&D costs of upgrading the injection line and Re-Injection girder.
1.2.1.4.4.1	PED Accel Systems Beam Transport Injector & Re-injection Dipoles	E&D of replacement or upgrades of BL, BD, and BK correctors.
1.2.1.4.4.2	PED Accel Systems Beam Transport Injector & Re-injection Quadrupoles	Not Used.
1.2.1.4.4.3	PED Accel Systems Beam Transport Injector & Re-injection Correctors	Not Used.
1.2.1.4.4.4	PED Accel Systems Beam Transport Injector & Re-injection Stands & Girders	Management of 1.2.1.4.4; E&D New Stands; Overall layout of new BT line. Design of Spectrometer move/upgrade.
1.2.1.4.4.5	Not used	Not Used.
1.2.1.4.4.6	PED Accel Systems Beam Transport Injector & Re-injection Vacuum	Vacuum chambers for new chicane.
1.2.1.4.4.7	PED Accel Systems Beam Transport Injector & Re-injection Installation	Not Used.

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1.2.1.4.5	PED Accel Systems Beam Transport Arc 10 & Hall D Beamline	E&D costs for the new Arc 10 and Hall D transport beamlines.
1.2.1.4.5.1	PED Accel Systems Beam Transport Arc 10 & Hall D Beamline Dipoles	Management and oversight of 1.2.1.4.5; E&D of 4 a new 4 meter dipole; prototyping costs.
1.2.1.4.5.2	PED Accel Systems Beam Transport Arc 10 & Hall D Beamline Quadrupoles	E&D of two new quadrupoles. E&D of correctors as needed.
1.2.1.4.5.3	PED Accel Systems Beam Transport Arc 10 & Hall D Beamline Correctors	Not Used.
1.2.1.4.5.4	PED Accel Systems Beam Transport Arc 10 & Hall D Beamline Stands	Overall layout and installation drawings of Arc 10 and the HALL D transport Line; new stands for dipole in Arc 10 and Hall D; new quad girder designs, new LCW and instrument air design.
1.2.1.4.5.5	PED Accel Systems Beam Transport Arc 10 & Hall D Beamline Girders	Not Used.
1.2.1.4.5.6	PED Accel Systems Beam Transport Arc 10 & Hall D Beamline Vacuum	Design 4 meter vacuum chamber; overall vacuum system design for Arc 10 and Hall D.
1.2.1.4.5.7	PED Accel Systems Beam Transport Arc 10 & Hall D Beamline LCW & Instrument Air	Not Used.
1.2.1.4.5.8	PED Accel Systems Beam Transport Arc 10 & Hall D Beamline Installation	Not Used.
1.2.1.4.6	PED Accel Systems Beam Transport Injector Recirculation	Not Used.
1.2.1.4.6.1	PED Accel Systems Beam Transport Injector Recirculation Dipoles	Not Used.
1.2.1.4.6.2	PED Accel Systems Beam Transport Injector Recirculation Quadrupoles	Not Used.
1.2.1.4.6.3	PED Accel Systems Beam Transport Injector Recirculation Correctors	Not Used.
1.2.1.4.6.4	PED Accel Systems Beam Transport Injector Recirculation Stands	Not Used.
1.2.1.4.6.5	PED Accel Systems Beam Transport Injector Recirculation Girders	Not Used.
1.2.1.4.6.6	PED Accel Systems Beam Transport Injector Recirculation Vacuum	Not Used.
1.2.1.4.6.7	PED Accel Systems Beam Transport Injector Recirculation Installation	Not Used.
1.2.1.5	PED Accel Systems Extraction	PED for Extraction system which encompasses RF Separator cavities and controls as well as the development of magnet systems that are specifically part of extracting beams.
1.2.1.5.1	PED Accel Systems Extraction Cavities	Engineering and design effort for adding 2 additional RF separator cavities to the existing system.
1.2.1.5.2	PED Accel Systems Extraction RF Components	Engineering and design effort for RF and HV components necessary to incorporate 2 new additional RF Separator cavities and relocate 3 existing cavities.

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1.2.1.5.3	PED Accel Systems Extraction Resonance Control	Engineering and Design effort for expansion of the Resonance Control System to support 2 additional and 3 relocated RF Separator cavities.
1.2.1.5.4	PED Accel Systems Extraction Lambertson	Engineering and design effort to modify the Beam Switchyard Lambertson magnet to make it 12 GeV ready.
1.2.1.5.5	PED Accel Systems Extraction Septa and Dipoles	Engineering and design effort to build 7 BP dipole magnets and 2 YA septum magnets.
1.2.1.5.6	PED Accel Systems Extraction Stands	Engineering and design effort for the relocation of 3 RF cavities and 5 magnets, support stands, and survey and alignment planning.
1.2.1.6	PED Accel Systems Instrumentation, Controls, and Safety Systems	Procurements and engineering, technician and software manpower for Engineering Design for beam diagnostics, feedback, control system infrastructure, machine protection system, personnel safety system, instrumentation and controls for dumps, vacuum and mag.
1.2.1.6.1	PED Accel Systems Instrumentation, Controls, and Safety Systems Beam Diagnostics	Engineering design for beam diagnostic devices for extraction, Arc 10 and Hall D beamline.
1.2.1.6.1.1	PED Accel Systems Instrumentation, Controls, and Safety Systems Beam Diagnostics BPM's	Engineering design for beam position monitors for extraction, Arc 10 and Hall D beamline.
1.2.1.6.1.2	PED Accel Systems Instrumentation, Controls, and Safety Systems Beam Diagnostics Harps	Engineering design for beam profile monitors (aka Harps) for extraction, Arc 10 and Hall D beamline.
1.2.1.6.1.3	PED Accel Systems Instrumentation, Controls, and Safety Systems Beam Diagnostics Viewers	Engineering design for beam viewers for extraction, Arc 10 and Hall D beamline.
1.2.1.6.1.4	PED Accel Systems Instrumentation, Controls, and Safety Systems Beam Diagnostics Beam-based Feedback Systems	Engineering design for fast feedback system for Hall D.
1.2.1.6.2	PED Accel Systems Instrumentation, Controls, and Safety Systems Control System Hardware	Engineering design for controls hardware infrastructure including network to Hall D.
1.2.1.6.3	PED Accel Systems Instrumentation, Controls, and Safety Systems Control System Software	Engineering design for software for global controls and beam applications.
1.2.1.6.4	PED Accel Systems Instrumentation, Controls, and Safety Systems Safety Systems	Engineering design for machine protection and personnel safety systems associated with accelerator upgrade and Hall D.
1.2.1.6.4.1	PED Accel Systems Instrumentation, Controls, and Safety Systems Safety Systems Machine Protection	Engineering design for machine protection systems needed to support Arc 10, Hall D and newly instrumented accelerator zones.
1.2.1.6.4.2	PED Accel Systems Instrumentation, Controls, and Safety Systems Safety Systems BELS	Engineering design for beam envelope protection systems needed to support Hall D.
1.2.1.6.4.3	PED Accel Systems Instrumentation, Controls, and Safety Systems Safety Systems PSS	Engineering design for personnel safety systems needed to support Arc 10, Hall D and newly instrumented accelerator zones.
1.2.1.6.5	PED Accel Systems Instrumentation, Controls, and Safety Systems Insertable Dump	Engineering design for instrumentation and controls for Arc 10 and Hall D line beam dumps.
1.2.1.6.6	PED Accel Systems Instrumentation, Controls, and Safety Systems Vacuum Controls	Engineering design for vacuum instrumentation and controls for ARC 10 and newly installed cryomodules in the accelerator.
1.2.1.6.7	PED Accel Systems Instrumentation, Controls, and Safety Systems Magnet Instrumentation	Engineering design for instrumentation and controls for new magnets and power supplies in Arc 10 and Hall D line.
1.2.1.7	Not used	Not Used.
1.2.2	PED Upgrade Hall A, B & C	Project Engineering and Design for Halls A, B, and C.

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1.2.2.1	PED Upgrade Hall A	Project Engineering and Design for Hall A.
1.2.2.1.1	PED Upgrade Hall A Magnet	Not Used.
1.2.2.1.1.1	PED Upgrade Hall A Magnet Combined Function Magnet	Not Used.
1.2.2.1.1.2	PED Upgrade Hall A Magnet Cryogenic System	Not Used.
1.2.2.1.1.3	PED Upgrade Hall A Magnet Power Supply	Not Used.
1.2.2.1.1.4	PED Upgrade Hall A Magnet Shield House	Not Used.
1.2.2.1.1.5	PED Upgrade Hall A Magnet Support Structure & Motion System	Not Used.
1.2.2.1.1.6	PED Upgrade Hall A Magnet Control System	Not Used.
1.2.2.1.1.7	PED Upgrade Hall A Magnet Septum	Not Used.
1.2.2.1.2	PED Upgrade Hall A Detectors	Not Used.
1.2.2.1.2.1	PED Upgrade Hall A Detectors Trigger System (Scintillators)	Not Used.
1.2.2.1.2.2	PED Upgrade Hall A Detectors Tracking System (Drift Chambers)	Not Used.
1.2.2.1.2.3	PED Upgrade Hall A Detectors Gas Cerenkov	Not Used.
1.2.2.1.2.4	PED Upgrade Hall A Detectors Aero gel Cerenkov	Not Used.
1.2.2.1.2.5	PED Upgrade Hall A Detectors Calorimeter	Not Used.
1.2.2.1.2.6	PED Upgrade Hall A Detectors Focal Plane Polarimeter	Not Used.
1.2.2.1.3	PED Upgrade Hall A Computing	Engineering and design for the DAQ upgrade of HRS.
1.2.2.1.3.1	PED Upgrade Hall A Computing DAQ for MAD	Engineering and design for the DAQ upgrade of HRS.
1.2.2.1.3.2	PED Upgrade Hall A Computing DAQ Upgrade for HRS	Not Used.
1.2.2.1.4	PED Upgrade Hall A Computing Fast Electronics	Not Used.
1.2.2.1.5	PED Upgrade Hall A Beamline	Engineering and design for Hall A beamline upgrades.
1.2.2.1.5.1	PED Upgrade Hall A Beamline Moller Polarimeter Upgrade	Engineering and design for Hall A beamline upgrades.
1.2.2.1.5.2	PED Upgrade Hall A Beamline Compton Polarimeter Upgrade	Design beamline modifications and new magnetic shielding for dipole.

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WBS	Description	Dictionary
1.2.2.1.5.3	PED Upgrade Hall A Beamline Mapping-Arc Energy Measurement	Design beamline modifications Design detector and motion system.
1.2.2.1.6	PED Upgrade Hall A Infrastructure	Not Used.
1.2.2.1.6.1	PED Upgrade Hall A Infrastructure Engineering & Design	Not Used.
1.2.2.1.6.2	PED Upgrade Hall A Infrastructure Cabling	Not Used.
1.2.2.1.6.3	PED Upgrade Hall A Infrastructure Installation	Not Used.
1.2.2.2	PED Upgrade Hall B	PED for CLAS12 (Detectors and Magnets), Computing Beamline, Infrastructure and Installation.
1.2.2.2.1	PED Upgrade Hall B Magnet	PED for CLAS12 Superconducting Magnets: Torus and Solenoid.
1.2.2.2.2	PED Upgrade Hall B Detectors	PED Upgrade Hall B Detectors: Tracking, Calorimetry, Time of Flight, Cerenkov.
1.2.2.2.3	PED Upgrade Hall B Computing	PED Upgrade Hall B Computing.
1.2.2.2.4	PED Upgrade Hall B Electronics	Not Used.
1.2.2.2.5	PED Upgrade Hall B Beamline	PED Upgrade Hall B Beamline: Faraday Cup, Moller Polarimeter, Beamline Shielding.
1.2.2.2.6	PED Upgrade Hall B Infrastructure	PED Upgrade Hall B Infrastructure: Utilities, Mechanical Frames, Assembly and Installation.
1.2.2.3	PED Upgrade Hall C	Detailed engineering/design Hall C.
1.2.2.3.1	PED Upgrade Hall C Magnet	Detailed engineering/design of superconducting magnets for Hall C.
1.2.2.3.1.1	PED Upgrade Hall C Magnet Quadrupoles	Detailed engineering/design of Q1 quadrupole.
1.2.2.3.1.2	PED Upgrade Hall C Magnet HB, Q2/Q3, D	Detailed engineering and design of HB, Q2/3, and Dipole magnets.
1.2.2.3.2	PED Upgrade Hall C Detector	Design of Hall C detector package.
1.2.2.3.3	PED Upgrade Hall C Computing	Not Used.
1.2.2.3.4	PED Upgrade Hall C Electronics	Not Used.
1.2.2.3.5	PED Upgrade Hall C Beamline	Not Used.
1.2.2.3.6	PED Upgrade Hall C Infrastructure	Not Used.
1.2.3	PED Hall D	PED for all equipment and auxiliary support required to operate the GlueX detector in Hall D.

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WBS	Description	Dictionary
1.2.3.1	PED Hall D Solenoid	Not Used.
1.2.3.2	PED Hall D Detectors	PED of tracking detectors, calorimeters and particle identification detectors for Hall D.
1.2.3.2.1	PED Hall D Detectors Tracking	PED for detectors used to track charged particles in the magnetic field.
1.2.3.2.1.1	PED Hall D Detectors Tracking Forward Chambers	PED of tracking chambers for angles less than about 30 degrees.
1.2.3.2.1.2	PED Hall D Detectors Tracking Central Chambers	PED of tracking chambers for angles greater than about 10 degrees.
1.2.3.2.1.3	PED Hall D Detectors Tracking Start Counter	PED of detector surrounding target.
1.2.3.2.2	PED Hall D Detectors Calorimetry	PED for detectors required to measure energy of neutral particles in Hall D.
1.2.3.2.2.1	PED Hall D Detectors Calorimetry Barrel Calorimeter	PED of calorimetry between 10 and 140 degrees.
1.2.3.2.2.2	PED Hall D Detectors Calorimetry Forward Calorimeter	PED of lead glass calorimeter below 10 degrees.
1.2.3.2.2.3	PED Hall D Detectors Calorimetry Upstream Photon Veto	Not Used.
1.2.3.2.3	PED Hall D Detectors Particle ID	PED of technical issues related to charged particle identification with GlueX detector.
1.2.3.2.3.1	PED Hall D Detectors Particle ID Time-of-Flight	PED of scintillator detectors for particle identification by time-of-flight.
1.2.3.2.3.2	PED Hall D Detectors Particle ID Cerenkov Counter	PED of Cerenkov counter for particle identification.
1.2.3.3	PED Hall D Computing	PED for all DAQ, online and offline computing requirements for Hall D.
1.2.3.3.1	PED Hall D Computing DAQ	PED of data acquisition to handle the rates of several 100kHz in Hall D.
1.2.3.3.2	PED Hall D Computing Online Computing	PED of all online activities for Hall D.
1.2.3.3.3	PED Hall D Computing Offline Computing	PED for the offline computing (simulation, reconstruction, calibration) for Hall D.
1.2.3.4	PED Hall D Electronics	PED for all pipeline electronics, clock and trigger signal distribution for Hall D DAQ and Trigger.
1.2.3.5	PED Hall D Beamline	PED to develop high quality coherent bremsstranlung beam for use in Hall D.
1.2.3.5.1	PED Hall D Beamline Tagger	PED to develop system to tag the energy and time of photons incident on detector.
1.2.3.5.1.1	PED Hall D Beamline Tagging Magnet	PED of tagging magnet system for Hall D.

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1.2.3.5.1.2	PED Hall D Beamline Hodoscope	PED for focal plane detectors of tagging spectrometer.
1.2.3.5.2	PED Hall D Beamline Target	Not Used.
1.2.3.5.3	PED Hall D Beamline Components	PED of beamline associated with coherent bremsstrahlung beam.
1.2.3.6	PED Hall D Infrastructure	PED of infrastructure needed to operate the GlueX detector in Hall D.
1.2.3.6.1	PED Hall D Infrastructure Assembly	PED of detector assembly.
1.2.3.6.2	PED Hall D Infrastructure Installation	Not Used.
1.2.3.6.3	PED Hall D Infrastructure Cryogenics	Not Used.
1.2.4	PED Conventional Facilities	Engineering and design of new conventional facilities and modifications to existing conventional facilities to support the 12 GeV CEBAF Upgrade.
1.2.4.1	PED Conventional Facilities Accelerator	Engineering and design of additions to existing Accelerator service buildings and of modifications to utility distribution systems for CEBAF upgrade to 12 GeV.
1.2.4.2	PED Conventional Facilities CHL	Engineering and design of a building addition and upgrade utility systems to support CHL #2 operations.
1.2.4.3	PED Conventional Facilities Hall D	Engineering and design of the conventional facilities for a new experimental hall (Hall D), an extension of the accelerator tunnel, and support facilities including utilities.
1.2.5	PED Project Management	Project Management support for PED phase of 12 GeV Upgrade.
1.2.5.1	PED Project Management Project Office	Provide project management for the PED phase of the upgrade project. Includes Project Manager, Deputy Project Manager, Science Lead, Technical Lead, Integration Engineer, Safety Manager, Associate Project Managers and Administration.
1.2.5.2	PED Project Management Office of Project Management	Provide project services support for the PED phase of the upgrade project. Includes Project Management and Integration Office staff activities related to earned value management system activities.
1.2.6	PED Accelerator Systems Commissioning Planning	Development of Accelerator Commissioning Plan.
1.3	Construction Accelerator Systems	This summary WBS covers the construction of the cyromodules, power systems, cyrogenic systems, beam transport systems, extraction systems, and instrumentation, controls, & safety systems of the 12 GeV Upgrade accelerator.

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WBS	Description	Dictionary
1.3.1	Construction Accel Systems Cryomodules	This summary WBS covers the procurement, assembly, testing and installation of the 10 new accelerator cryomodules.
1.3.1.1	Construction Accel Systems Cryomodules Procurements	This summary WBS covers the procurement of the material and equipment needed for the 10 new accelerator cryomodules.
1.3.1.1.1	Construction Accel Systems Cryomodules Procurements Cavity String	This summary WBS covers the component and management costs for procuring 10 cavity strings. Components include Cavities 84 each, Niobium material for the cavities, Fundamental Power Coupler warm to cold waveguides 86 each, Miscellaneous Cavity String Components, HOM/Field Probes 90 each, Helium Vessels 88 each.
1.3.1.1.1.1	Construction Accel Systems Cryomodules Procurements Cavity String Niobium Procurement	This WBS element includes the component and management costs for procuring niobium material for 10 cavity strings.
1.3.1.1.1.2	Construction Accel Systems Cryomodules Procurements Cavity String Cavity Fabrication Procurement	This WBS element includes the component and management costs for procuring fabricated cavities for 10 cavity strings.
1.3.1.1.1.3	Construction Accel Systems Cryomodules Procurements Cavity String Waveguide Procurement	This WBS element includes the component and management costs for procuring fabricated waveguides for 10 cavity strings.
1.3.1.1.1.4	Construction Accel Systems Cryomodules Procurements Cavity String Helium Vessel Procurement	This WBS element includes the component and management costs for procuring fabricated Helium Vessels for 10 cavity strings.
1.3.1.1.1.5	Construction Accel Systems Cryomodules Procurements Cavity String Hardware Procurement	This WBS element includes the component and management costs for procuring Hardware for 10 cavity strings.
1.3.1.1.1.6	Construction Accel Systems Cryomodules Procurements Cavity String Miscellaneous Procurement	This WBS element includes the component and management costs for procuring Miscellaneous assembly items for 10 cavity strings.

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1.3.1.1.2	Construction Accel Systems Cryomodules Procurements Space Frame	This summary WBS covers the component and management costs for procuring 10 assemblies: 84 Tuner Assemblies, 10 Header Assemblies (Supply and Return),10 Magnetic Shield Assembly, 10 Thermal Shield Assembly, 10 sets MLI Blankets, Seals & Miscellaneous Space.
1.3.1.1.2.1	Construction Accel Systems Cryomodules Procurements Space Frame Space Frame Procurement	This WBS element includes the component and management costs for procuring fabricated Space Frames for 10 cavity strings.
1.3.1.1.2.2	Construction Accel Systems Cryomodules Procurements Space Frame Tuner Procurement	This WBS element includes the component and management costs for procuring fabricated Tuners for 10 cavity strings.
1.3.1.1.2.3	Construction Accel Systems Cryomodules Procurements Space Frame Helium Header Procurement	This WBS element includes the component and management costs for procuring fabricated Helium Headers for 10 cavity strings.
1.3.1.1.3	Construction Accel Systems Cryomodules Procurements Cryomodule	This summary WBS covers the component and management costs for procuring 10 assemblies: 10 Alignment Fiducials sets, 10 Vacuum Tank Assemblies each, 10 End Can Assemblies sets, 10 beamline Assembly Cryomodule sets, 10 Stands sets, Wiring Including HOM & 10 FP Cables.
1.3.1.1.3.1	Construction Accel Systems Cryomodules Procurements Cryomodule MLI Procurement	This WBS element includes the component and management costs for procuring MLI material for 10 cryomodules.
1.3.1.1.3.2	Construction Accel Systems Cryomodules Procurements Cryomodule Thermal Shield Procurement	This WBS element includes the component and management costs for procuring fabricated Thermal Shields for 10 cryomodules.
1.3.1.1.3.3	Construction Accel Systems Cryomodules Procurements Cryomodule Magnetic Shield Procurement	This WBS element includes the component and management costs for procuring fabricated Magnetic Shields for 10 cryomodules.
1.3.1.1.3.4	Construction Accel Systems Cryomodules Procurements Cryomodule Instrumentation Procurement	This WBS element includes the component and management costs for procuring measurement and monitoring Instrumentation for 10 cryomodules.
1.3.1.1.3.5	Construction Accel Systems Cryomodules Procurements Cryomodule End Can Procurement	This WBS element includes the component and management costs for procuring fabricated End Cans for 10 cryomodules.
1.3.1.1.3.6	Construction Accel Systems Cryomodules Procurements Cryomodule Vacuum Vessel Procurement	This WBS element includes the component and management costs for procuring fabricated Vacuum Vessels for 10 cryomodules.
1.3.1.1.3.7	Construction Accel Systems Cryomodules Procurements Cryomodule Beam Pipe Procurement	This WBS element includes the component and management costs for procuring fabricated Beam Pipes for 10 cryomodules.
1.3.1.1.3.8	Construction Accel Systems Cryomodules Procurements Cryomodule Top Hat Procurement	This WBS element includes the component and management costs for procuring fabricated Top Hats for 10 cryomodules.
1.3.1.1.3.9	Construction Accel Systems Cryomodules Procurements Cryomodule Support Procurement	This WBS element includes the component and management costs for procuring fabricated Supports for 10 cryomodules.
1.3.1.1.4	Construction Accel Systems Cryomodules Procurements Installation & Assembly Tooling	The WBS element includes procurement of 2 helium vessel weld tooling sets, 1 VTA insert modification set, 1 cavity string support tooling set, 1 cryomodule tunnel installation wheel assembly set, and various small jigs and fixtures.
1.3.1.1.5	Not Used	Not Used.
1.3.1.2	Construction Accel Systems Cavity String Assembly	This WBS element includes the labor and supplies to process and assemble the 10 cavity strings.
1.3.1.3	Construction Accel Systems Cryomodule Assembly	This summary WBS covers the labor and supplies to assemble the 10 cryomodules.
1.3.1.3.1	Construction Accel Systems Cryomodule Assembly Space Frame Sub-assembly	This WBS element includes the labor and supplies to assemble the 10 space frames sub-assemblies.

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1.3.1.3.2	Construction Accel Systems Cryomodule Assembly Cryomodule Assembly	This WBS element includes the labor and supplies to complete the cryomodule assembly of 10 space frames sub-assemblies.
1.3.1.4	Construction Accel Systems Acceptance Testing	This WBS element includes the labor and supplies to perform acceptance testing in the Test Lab CMTF for 10 cryomodules.
1.3.1.5	Construction Accel Systems Installation	This WBS element includes the labor for installation of 10 cryomodules including installation, alignment, and vacuum work.
1.3.1.6	Construction Accel Systems Microphonics	This WBS element determines level of microphonics projected for operations in the accelerator tunnel and begin development of potential mitigations.
1.3.1.7	Technology & Engineering Development Facility (TEDF) Interface	This WBS element includes the dates of the four TEDF down times and the workcenter transition anticipated to take place during 2010 through 2012. This information is for scheduling activities associated with facility availability.
1.3.2	Construction Accel Systems Power Systems	This summary WBS covers the equipment and installation of the accelerator RF and magnet power systems.
1.3.2.1	Construction Accel Systems Power Systems RF	This summary WBS covers the high power & low level RF system equipment and installation: 10 new zones of 8 cavities x 13 kW/cavity.
1.3.2.1.1	Construction Accel Systems Power Systems RF Power	This summary WBS covers the high power RF system equipment and installation: 10 zones, 80 cavities.
1.3.2.1.1.1	Construction Accel Systems Power Systems RF Klystrons	This WBS element includes the procurement and testing of the 13kW RF Power Source: 10 zones, 80 RF Power Devices (Tubes).
1.3.2.1.1.2	Construction Accel Systems Power Systems RF DC Power	This summary WBS covers the procurement, assembly, installation, and testing of the HV DC Power systems and HPA assembly and support electronics: 10 zones Includes 10 HV DC power supplies, RF source (tube) support electronics, interlocks and controls as well as mechanical assembly for mounting all hardware.
1.3.2.1.1.2.1	Construction Accel Systems Power Systems RF HV DC Power Supplies	This WBS element includes the procurement, installation, and testing of 10 HV DC Power Supplies, each supplying power to eight 13 kW CW klystrons.
1.3.2.1.1.2.2	Construction Accel Systems Power Systems RF HPA Systems	This WBS element includes the procurement, assembly, installation, and testing of HPA (High Power Amplifier) systems for 10 zones. Systems include auxiliary electronics (filament, mod anode, solenoid power supplies, etc.), interlocks and interfaces to external systems and controls, cabinets, and support structures to accommodate eight klystrons and associated equipment.
1.3.2.1.1.3	Construction Accel Systems Power Systems RF Waveguide Components	This WBS element includes procurement and installation of circulators, couplers, and waveguide plumbing for 10 zones and connections from the high power RF device output to the cavity input for 80 cavities. Also includes 40 HOM waveguide filters.
1.3.2.1.2	Construction Accel Systems Power Systems RF Control	This summary WBS covers the low level RF system equipment procurement, construction and installation for 80 cavities.
1.3.2.1.2.1	Construction Accel Systems Power Systems RF Control Field Control (RF items)	This WBS element includes procurement, building, testing and installation of 80 LLRF control modules and support hardware for cavity gradient and phase control.
1.3.2.1.2.2	Construction Accel Systems Power Systems RF Control Resonance Control & Interlocks (interlocks, tuner controls)	This WBS element includes procurement, building, testing and installation of cavity tuning electronics and cavity interlocks and includes 80 Stepper motor controls, 80 Piezo electric tuner controls, 10 zones of cavity and system interlocks.
1.3.2.1.2.3	Construction Accel Systems Power Systems RF Control Packaging/Interface (racks, crates)	This WBS element includes procurement, building, testing and installation of racks & interface for cavity LLRF, tuning and interlock controls and includes 2 racks per zone, cable and interconnect hardware, auxiliary power supplies.

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1.3.2.1.2.4	Construction Accel Systems Power Systems RF Control CPU & Software	This WBS element includes procurement, building, testing and installation of LLRF embedded IOC and communications hardware. The WBS element also includes the development and check software/EPICS interface for 10 zones and includes 11 PC104 processors and associated hardware per zone.
1.3.2.1.2.5	Construction Accel Systems Power Systems RF Control Test Stand	This WBS element includes the build of offline test stands for LLRF controls calibration and testing.
1.3.2.1.2.6	Not Used	Not Used.
1.3.2.1.2.7	Construction Accel Systems Power Systems RF Control HPA Controls	This WBS element includes procurement, building, testing and installation of a HPA controller for 10 zones of new RF.
1.3.2.1.3	Construction Accel Systems RF Installation & System Commissioning (test equipment, system integration labor)	This WBS element includes the procurement, assembly and program testing of the stand equipment required for RF source and cryomodule integration commissioning. Commissioning labor for 10 zones of SRF is included. Tests include system set-up, optimization and integration. Verification and acceptance tests are performed to insure that all field control and other system requirements are met. Deliverables are 10 zones of operational SRF for accelerator use.
1.3.2.1.4	Not Used	Not Used.
1.3.2.2	Construction Accel Systems Magnet Power	This summary WBS covers the procurement and installation of all magnet power supply upgrades including: New box PS, refurbished box PS, new trim PS and additional 10 amp trims, load, control and interlock cable, check out and testing of all systems.
1.3.2.2.1	Construction Accel Systems Magnet Power Box Supplies	This WBS element includes the procurement, building, testing and placement for installation 35 Box Power Supplies. This WBS element also includes preparing existing power supplies for re-use, modifying existing supplies for different operating ranges and procuring new power supplies in the range of 40 kW to 1000 kW for Arcs Septa and Transport line magnets.
1.3.2.2.2	Construction Accel Systems Magnet Power Shunts	This WBS element includes all the upgrades (design and construction) necessary for the shunt system for the project. The upgrade requires: new 25 amp shunts (15 units); new 75 amp YA power supplies, bulk power supplies and pre-regulators (4 systems); water cooled shunt resistors (85 units) and; construction of additional 20 amp shunt chassis (5 units). Also included is the reconditioning and reconfiguration of the existing shunt hardware (~75 units) to accommodate the new 12 GEV magnet powering scheme and the removal of equipment that is no longer used. Final installation testing and documentation are part of the work scope.
1.3.2.2.3	Construction Accel Systems Magnet Power Trims	This WBS element includes the procurement and installation of 260 new 20 Amp trims power supplies, (0) additional existing 10 Amp trim cards, 3 new 10 amp trim racks, 28 rack assemblies for 20 amp trims, and supporting controls interface hardware. The Synchrotron Radiation Correction Coils system requires 4 power supplies capable of approximately 40 volts and a 2 amps. The coils are embedded in the main dipoles for Arcs 7,8,9 and 10 and will be powered in series in each Arc. New cable must be installed to connect the loads for this system. Four power supplies and cabling will be installed and connected to the synch.rad. coils embedded in the dipole magnets in Arcs 7, 8, 9, and 10. These power supplies and coils compensate for the orbit change due to energy lost due to synchrotron radiation by the electron beam.
1.3.2.2.4	Construction Accel Systems Magnet Power Installation	This WBS element includes the procurement and installation: load, AC power, control and interlock cable; cable tray, junction boxes, LCW manifolds, and misc hardware for trims, and Box PS. This WBS element also includes the installation of 28 trim rack assemblies; relocation and placement of re-used Trim and Box PS; connection, check, and testing of all equipment. Cable required: 20kft of 535MCM DC power cable, 49kft of #10 AWG trim cable, 47kft of interlock & controls cable.

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1.3.3	Construction Accel Systems Cryogenics	This summary WBS covers the construction phase of upgrading the cryogenics system.
1.3.3.1	Construction Accel Systems Cryogenics Accelerator	This summary WBS covers the construction of a 46kW @ 2K cryogenics plant for cooling the accelerator cryomodules.
1.3.3.1.1	Construction Accel Systems Cryogenics Compressors	This WBS element includes the 12 GeV CHL Main warm helium compressor equipment purchase and field placement installation costs.
1.3.3.1.2	Construction Accel Systems Cryogenics Cold Boxes	This WBS element includes the new CHL 4K Cold box equipment purchase and placement installation cost 2K Cold box exists.
1.3.3.1.3	Construction Accel Systems Cryogenics Oil Removal Skids	This WBS element includes the Warm Helium Final Oil Removal Equipment purchase, assembly, and placement installation costs.
1.3.3.1.4	Not Used	Not Used.
1.3.3.1.5	Not Used	Not Used.
1.3.3.1.6	Construction Accel Systems Cryogenics CHL Gas Management Rack	This WBS element includes the materials procurement, fabrication, and field placement for the warm helium compressor gas management valve rack assembly.
1.3.3.1.7	Construction Accel Systems Cryogenics CHL System Instrumentation and Controls	This WBS element includes the Control System Control System fabrication and major component field placement for the CHL 4K cold box, compressors and associated subsystems.
1.3.3.1.8	Construction Accel Systems Cryogenics Instrument Air System and Support Equipment	This WBS element includes the purchase, installation and field placement costs of new instrumentation air system for the new CHL refrigerator system.
1.3.3.1.9	Construction Accel Systems Cryogenics Motor Control Centers	This WBS element includes the purchase and installation of the 4160V and 480V motor control center lineups for the CHL warm helium compressors.
1.3.3.1.10	Construction Accel Systems Cryogenics CHL Installation and Design	This WBS element includes the interconnecting piping, electrical, and instrumentation wiring installation for the new CHL refrigerator system.
1.3.3.1.11	Construction Accel Systems Cryogenics CHL Commissioning	This WBS element includes the start up and performance testing of the major CHL component subsystems.
1.3.3.1.12	Construction Accel Systems Cryogenics Linac Transfer Line	This WBS element includes the fabrication of new u-tubes and connection hardware for new 12GeV cryomodules.
1.3.3.2	Construction Accel Systems Hall D	This summary WBS covers the construction of a 4K cryogenics system for the Hall D solenoid.
1.3.3.2.1	Construction of Hall D Transfer Line and Solenoid Distribution Can	This WBS element includes the construction and field installation of the Hall D transfer line and solenoid distribution can.
1.3.3.2.2	Construction Accel Systems Hall D Cold Box	This WBS element includes the installation and assembly of the Hall D Refrigerator.
1.3.3.2.3	Construction Accel Systems Hall D Distribution System	This WBS element includes the field installation of the Hall D refrigerator warm gas piping and mechanical components.
1.3.3.2.4	Construction Accel Systems Hall D Instrumentation and Controls	This WBS element includes the field installation and construction of the Hall D refrigerator control panels and interconnecting wiring.
1.3.3.2.5	Construction Accel Systems Hall D U-Tubes	This WBS element includes the fabrication of the Hall D refrigerator to Hall D transfer line u-tubes.
1.3.3.2.6	Construction Accel Systems Hall D Field Installation	This WBS element includes the Hall D refrigerator process piping and piping support installation from the refrigerator equipment to Hall D transfer line connection.
1.3.3.2.7	Construction Accel Systems Hall D Commissioning	This WBS element includes the commissioning and performance testing of the Hall D refrigerator.
1.3.4	Construction Accel Systems Beam Transport	This summary WBS covers the construction phase of upgrading the beam transport system for the accelerator.

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1.3.4.1	Construction Accel Systems Beam Transport Spreaders & Recombiners	This summary WBS covers the construction costs for reworking the 5 CEBAF spreaders & recombiners.
1.3.4.1.1	Construction Accel Systems Beam Transport Spreaders & Recombiners Dipoles	This WBS element includes management, travel and expenses for procurement of Magnets [3 Two meter dipoles, 10 curved dipoles, 3 one and one half meter dipoles, 7 BP dipoles, 8 three meter septa, 3 modified 2 meter septa, 2 YA septa and spare coils for each], 45 H-iron for AA and AI cores, BComm return steel, misc magnet parts for rebuild. This WBS element also includes labor to rebuild S/R dipoles and the QC and magnet measurement of S/R dipoles and Septa.
1.3.4.1.2	Not Used	Not Used.
1.3.4.1.3	Not Used	Not Used.
1.3.4.1.4	Construction Accel Systems Beam Transport Spreaders & Recombiners Stands	This WBS element includes the procurement and QC of new stands, pedestals and brackets; the procurement and QC of alignment cartridges, mounting hardware for dipoles, quadrupoles, and diagnostics.
1.3.4.1.5	Not Used	Not Used.
1.3.4.1.6	Construction Accel Systems Beam Transport Spreaders & Recombiners Vacuum	This WBS element includes the procurement of dipole vacuum chambers; the procurement of additional vacuum drift tubes, etc; the procurement of misc seals, bolts, etc; the rebuilding of new and modified quad girders; and the vacuum installation labor for rebuilding the spreaders and recombiners.
1.3.4.1.7	Construction Accel Systems Beam Transport Spreaders & Recombiners Installation	This WBS element includes the labor to install stands, dipoles and quads girders; the alignment labor for spreaders and recombiners; the misc materials for installation; LCW hoses; the labor for planning installation; and the labor for inventory of incoming parts.
1.3.4.2	Construction Accel Systems Beam Transport Existing Arcs (1-9, A, B, & C)	This summary WBS covers the construction costs for reworking the CEBAF arcs and Hall A, B, & C transport.
1.3.4.2.1	Construction Accel Systems Beam Transport Existing Arcs (1-9, A, B, & C) Dipoles	This WBS element includes the management for procurement and QC of H-steel additions for all 9 existing ARCs; Hall Lines B, & C; travel; procurement of misc parts for dipole refurbishment.
1.3.4.2.2	Construction Accel Systems Beam Transport Existing Arcs (1-9, A, B, & C) Quadrupoles	This WBS element includes the procurement of 46 new quadrupoles for existing arcs and Spreader Recombiners; the magnet measurement of new quadrupoles; the addition of temperature switches for 20amp quadrupoles.
1.3.4.2.3	Not Used	Not Used.
1.3.4.2.4	Construction Accel Systems Beam Transport Existing Arcs (1-9, A, B, & C) Stands & Girders	This WBS element includes the procurement of new alignment cartridge caps and brackets for modified dipoles.
1.3.4.2.5	Not Used	Not Used.

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1.3.4.2.6	Construction Accel Systems Beam Transport Existing Arcs (1-9, A, B, & C), Arc Vacuum	Not Used.
1.3.4.2.7	Construction Accel Systems Beam Transport Existing Arcs (1-9, A, B, & C) Installation	This WBS element includes the installation labor for the removal and reinstallation of ARC dipoles; for the removal and reinstallation of hall line quad changes; for aligning Arcs 1-9, Halls A, B, & C. This WBS element also includes misc installation supplies, technician training and engineering support for installation.
1.3.4.3	Construction Accel Systems Beam Transport Linacs	This summary WBS covers the construction costs for accommodating 10 new high gradient cryomodules.
1.3.4.3.1	Not Used	Not Used.
1.3.4.3.2	Construction Accel Systems Beam Transport Linacs Correctors	This WBS element includes the procurement, QC and magnet measurement of new correctors for Linacs and injection line.
1.3.4.3.3	Construction Accel Systems Beam Transport Linacs Stands & Girders	This WBS element includes the procurement of 11 new pedestals and warm girders for linacs, including vacuum tube and bellows.
1.3.4.3.4	Not Used	Not Used.
1.3.4.3.5	Construction Accel Systems Beam Transport Linacs Vacuum	This WBS element includes the procurement of misc vacuum material; and the procurement of 11 new DI Ion Pumps. This WBS element also includes vacuum labor for assembly and installation of warm girders.
1.3.4.3.6	Construction Accel Systems Beam Transport Linacs Installation	This wbs element includes the removal and re-installation and alignment of 10 warm region girders.
1.3.4.4	Construction Accel Systems Beam Transport Injector & Re-injection	This summary WBS covers the construction costs of upgrading the injection line and re-injection girder.
1.3.4.4.1	Construction Accel Systems Beam Transport Injector & Re-injection Dipoles	This WBS element includes the procurement, QC and magnet measurement of replacements of four BL, and three BK dipoles.
1.3.4.4.2	Not Used	Not Used.
1.3.4.4.3	Not Used	Not Used.
1.3.4.4.4	Construction Accel Systems Beam Transport Injector & Re-injection Stands & Girders	This WBS element includes the management for the procurement of pedestals, girders and alignment cartridges for 5 new quad girders; the procurement of pedestals for girders shifting over the transfer lines and new reinjection chicane girder; and the upgrade cost for the existing 45 MeV spectrometer.
1.3.4.4.5	Not Used	Not Used.
1.3.4.4.6	Construction Accel Systems Beam Transport Injector & Re-injection Vacuum	This WBS element includes the procurement of ~4m of new vacuum tube drifts and 2 welded vacuum chambers; and the modification or reuse of ~29m of exiting beamline. This WBS element also includes the misc vacuum material and the labor for vacuum installation.

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1.3.4.4.7	Construction Accel Systems Beam Transport Injector & Re-injection Installation	This WBS element includes the rework of the injector transport line from after VBV0L06B to MBL0R03 and includes the 45 MeV spectrometer. This WBS element also includes the misc material for installation, grout, LCW, etc.; the labor for removal of existing stands; the labor to install new stands and water, air hook up; the labor to relocate the 45 MeV spectrometer; and the labor for alignment.
1.3.4.5	Construction Accel Systems Beam Transport Arc 10 & Hall D Beamline	This summary WBS covers the construction costs for the new Arc 10 and Hall D transport beamlines.
1.3.4.5.1	Construction Accel Systems Beam Transport Arc 10 & Hall D Beamline Dipoles	This WBS element includes the management and oversight for the procurement of 37 four-meter dipoles for Arc 10 and Hall D; the QC and magnet measurement of the dipoles; the alignment fixtures, and travel costs.
1.3.4.5.2	Construction Accel Systems Beam Transport Arc 10 & Hall D Beamline Quadrupoles & Correctors	This WBS includes the procurement, QC and magnet measurement of 69 new quadrupoles; temperature switches for 20amp quadrupoles; and procurement, QC and magnet measurement of new corrector magnets.
1.3.4.5.3	Not Used	Not Used.
1.3.4.5.4	Construction Accel Systems Beam Transport Arc 10 & Hall D Beamline Stands & Girders	This WBS includes the procurement and QC of new pedestals and quad girders for ARC 10 and Hall D transport; and 10 specialty girders and stands for diagnostics. This WBS also includes all hardware, alignment cartridges, etc for both; two new insertable dumps; and the modifications and infrastructure for the NE Stub dump to be used in the tagger building.
1.3.4.5.5	Not Used	Not Used.
1.3.4.5.6	Construction Accel Systems Beam Transport Arc 10 & Hall D Beamline Vacuum	This WBS includes the procurement and QC of the 37 dipole chambers for arc 10 and hall D; Ion pumps; drift tubes totaling to 70m for Arc 10 and 150m for Hall D; 3 specialty welded vacuum chambers; beamline vacuum valves; vacuum roughing valves, and misc vacuum hardware/gaskets/bolts/vacuum tubes. This WBS also includes assembly of quad girders and all labor for vacuum installation.
1.3.4.5.7	Not Used	Not Used.
1.3.4.5.8	Construction Accel Systems Beam Transport Arc 10 & Hall D Beamline Installation	This WBS includes Arc 10 pedestal installation, Hall D line installation labor, LCW Pipe/ Manifold costs, alignment labor, and installation materials; Hall D alignment network and installation of tagger dump and shielding. This WBS also includes installation for D transport shielding chicane wall.
1.3.4.6	Construction Accel Systems Transport Channel Magnets and Stands	This summary WBS covers the construction costs for the transport channel magnets and associated stands.
1.3.4.6.1	Construction Accel Systems Transport Lambertson	This WBS element includes the modification and checkout of the existing Beam Switchyard Lambertson magnet.
1.3.4.6.2	Construction Accel Systems Transport Septa and Dipoles	This WBS element includes procurement support, fabrication oversight and measurement and checkout of new and modified extraction dipole magnets and YA septum magnets and vacuum chambers.
1.3.4.6.3	Construction Accel Systems Transport Stands	This WBS element includes the fabrication and installation of support stands for 2 new and 3 relocated RF separator cavities, 2 new YA magnets, 7 new extraction dipole magnets, 3 relocated YR septum magnets and 1 modified Lambertson magnet.
1.3.4.6.4	Not Used	Not Used.

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1.3.4.6.5	Not Used	Not Used.
1.3.4.6.6	Not Used	Not Used.
1.3.4.6.7	Not Used	Not Used.
1.3.5	Construction Accel Systems Extraction	This summary WBS covers the construction for the extraction system which encompasses RF separator cavities and controls that are specifically part of extracting beams.
1.3.5.1	Construction Accel Systems Extraction Cavities	This WBS element includes the fabrication, assembly, installation and checkout for 2 RF separator cavities.
1.3.5.2	Construction Accel Systems Extraction RF Components	This WBS element includes the assembly, installation and checkout of RF and HV components to incorporate 2 additional RF separator cavities.
1.3.5.3	Construction Accel Systems Extraction Resonance Control	This WBS element includes the assembly, installation and checkout for separator cavity Resonance Control System.
1.3.5.4	Construction Accel Systems Extraction Lambertson	This WBS element includes the modification and checkout of the existing Beam Switchyard Lambertson magnet.
1.3.5.5	Construction Accel Systems Extraction Septa and Dipoles	This WBS element includes support for the fabrication and checkout of 7 BP dipole magnets and 2 YA septum magnets.
1.3.5.6	Construction Accel Systems Extraction Stands	This WBS element includes the fabrication and installation of support stands for 2 new and 3 relocated RF separator cavities, 2 new YA magnets, 7 new BP dipole magnets, 3 relocated YR septum magnets and 1 modified Lambertson magnet.
1.3.6	Construction Accel Systems Instrumentation, Controls, and Safety Systems	This summary WBS covers the procurements, fabrication, construction, installation and testing for beam diagnostics, feedback, control system, machine protection system, personnel safety system, instrumentation and controls for dumps, vacuum and magnets in support of the 12 GeV Upgrade.
1.3.6.1	Construction Accel Systems Instrumentation, Controls, and Safety Systems Beam Diagnostics	This summary WBS covers the procurements, fabrication, construction, installation and testing for beam diagnostics needed for the 12 GeV upgrade.
1.3.6.1.1	Construction Accel Systems Instrumentation, Controls, and Safety Systems Beam Diagnostics BPMs	This WBS element includes the procurement, fabrication, construction, installation and testing of 88 beam position monitors, 2 nA beam position monitors and 2 beam current monitors.
1.3.6.1.2	Construction Accel Systems Instrumentation, Controls, and Safety Systems Beam Diagnostics Harps	This WBS element includes the procurement, fabrication, construction, installation and testing of 6 beam profile monitors.
1.3.6.1.3	Construction Accel Systems Instrumentation, Controls, and Safety Systems Beam Diagnostics Viewers	This WBS element includes the procurement, fabrication, construction, installation and testing of 17 viewers and 3 synchrotron light monitors.
1.3.6.1.4	Construction Accel Systems Instrumentation, Controls, and Safety Systems Beam Diagnostics Beam-based Feedback Systems	This WBS element includes the procurement, fabrication, construction, installation and testing for fast feedback system for Hall D.

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1.3.6.2	Construction Accel Systems Instrumentation, Controls, and Safety Systems Control System Hardware	This WBS element includes the procurement, fabrication, construction, installation and testing for control system hardware infrastructure including network extension to Hall D, 13 VME crates, 14 IOCs, 13 console servers, 22 racks, 2 gateways and addition disk and CPU capacity.
1.3.6.3	Construction Accel Systems Instrumentation, Controls, and Safety Systems Control System Software	This WBS element includes the procurement, fabrication, construction, installation and testing for control system software infrastructure including modifications to global applications and beam applications.
1.3.6.4	Construction Accel Systems Instrumentation, Controls, and Safety Systems Safety Systems	This summary WBS covers the procurement, fabrication, construction, installation and testing for machine protection and personnel safety systems associated with accelerator upgrade and Hall D.
1.3.6.4.1	Construction Accel Systems Instrumentation, Controls, and Safety Systems Safety Systems Machine Protection	This WBS element includes the procurement, fabrication, construction, installation and testing for machine protection system upgrades including: 1 beam loss ion chamber, 4 BLM cards, 6 FSD cards, 3 BLMs, 2 BLM HVPS.
1.3.6.4.2	Construction Accel Systems Instrumentation, Controls, and Safety Systems Safety Systems BELS	This WBS element includes the procurement, fabrication, construction, installation and testing for beam envelope system upgrades including: 2 current monitor interfaces, 3 energy monitor interfaces, 1 EPICS interface, 10 field termination points, 1 rack and 1 PLC remote I/O.
1.3.6.4.3	Construction Accel Systems Instrumentation, Controls, and Safety Systems Safety Systems PSS	This WBS element includes the procurement, fabrication, construction, installation and testing for personnel protection system upgrades including: PLC based PSS system extension for Hall D and tagger areas, interfaces for 10 new cryomodules, magnet interfaces, and 13 run/safe boxes. ODH systems for Hall D and tagger areas.
1.3.6.5	Construction Accel Systems Instrumentation, Controls, and Safety Systems Insertable Dump	This WBS element includes the procurement, fabrication, construction, installation and testing for instrumentation and controls for insertable dump in Arc 10 and beam dump in Hall D line.
1.3.6.6	Construction Accel Systems Instrumentation, Controls, and Safety Systems Vacuum Controls	This WBS element includes the procurement, fabrication, construction, installation and testing for instrumentation and controls for vacuum systems in Arc 10 and 10 new cryomodules, including: 57 ion pumps and 11 valves.
1.3.6.7	Construction Accel Systems Instrumentation, Controls, and Safety Systems Magnet Instrumentation	This WBS element includes the design, procurement, fabrication, construction, installation and testing for instrumentation and controls for 130 correctors and 102 quadrupoles.
1.4	Construction Upgrade Hall A, B & C	This summary WBS covers the Halls A, B, C construction for the 12 GeV Upgrade.
1.4.1	Construction Hall A	This summary WBS covers the Hall A construction for 12 GeV Upgrade and includes the beamline equipment upgrade.
1.4.1.1	Not Used	Not Used.

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1.4.1.1.1	Not Used	Not Used.
1.4.1.1.2	Not Used	Not Used.
1.4.1.1.3	Not Used	Not Used.
1.4.1.1.4	Not Used	Not Used.
1.4.1.1.5	Not Used	Not Used.
1.4.1.1.6	Not Used	Not Used.
1.4.1.1.7	Not Used	Not Used.
1.4.1.2	Not Used	Not Used.
1.4.1.2.1	Not Used	Not Used.
1.4.1.2.2	Not Used	Not Used.
1.4.1.2.3	Not Used	Not Used.
1.4.1.2.4	Not Used	Not Used.
1.4.1.2.5	Not Used	Not Used.
1.4.1.2.6	Not Used	Not Used.
1.4.1.3	Construction Hall A Proj Admin	This WBS element covers all project administration costs associated with Hall A work, in particular arranging for ARC magnet mapping and the needed data collection.
1.4.1.3.1	Not Used	Not Used.
1.4.1.3.2	Data Recording for Magnet Settings	Effort to define, set up and commission equipment to record precise magnet settings for beamline ARC to Hall A.
1.4.1.4	Not Used	Not Used.
1.4.1.5	Construction Hall A Beamline	This summary WBS covers the upgrade to the Hall A beamline to be compatible with 11 GeV beam energy. The scope involves beam energy and beam polarimetry (Moller and Compton polarimeters) measurements. The arc upgrade is part of Accelerator/Beam Transport scope.
1.4.1.5.1	Construction Hall A Beamline Moller Polarimeter Upgrade	This WBS element includes the rearrangement of the beamline elements and detector, the procurement of a 4th quad plus power supply to achieve required focusing power for 11-GeV beam energy, and the addition of magnetic shielding to detector elements

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1.4.1.5.2	Construction Hall A Beamline Compton Polarimeter Upgrade	This WBS element includes the “12 GeV Upgrade” of the Compton Polarimeter. This is a relatively small addition to an ongoing broader range of upgrades for 6-GeV operation that includes new detectors (electron and gamma), doubling of laser energy (IR to green), and a new optical cavity. The 12 GeV piece of the upgrade then involves rearrangement of the beamline allowing the use of the same magnets and magnetic fields for higher energy beam (i.e. a reduction in the bend required from each magnet), and Implementation of the motion system of the new electron detector. The motion system is needed to expand upon the energy range of the Compton Polarimeter.
1.4.1.5.3	Construction Hall A Beamline Mapping-Arc Energy Measurement	This WBS element includes the recalibration of the Arc energy measurement system for higher fields needed to deliver 11 GeV beam to Hall A. Effort involves a systematic movement of magnets from the tunnel to the existing 9th dipole mapper for measurement (such that knowledge of the fields will render a direct beam energy measurement) and return to the tunnel. An upgrade of the power supply required to power the arc magnets is also needed.
1.4.1.6	Not Used	Not Used.
1.4.1.6.1	Not Used	Not Used.
1.4.1.6.2	Not Used	Not Used.
1.4.1.6.3	Not Used	Not Used.
1.4.2	Construction Hall B	This summary WBS covers the Hall B construction for the 12 GeV Upgrade: Detectors (central Time-of-flight, barrel silicon vertex tracker, high threshold Cerenkov counter, six sectors of three regions of drift chambers, six sectors of three panels (one new, two refurbished) of time-of-flight system, six sectors of preshower calorimeter, six sectors of refurbished low threshold Cerenkov counter), Superconducting Magnets (superconducting Torus, superconducting solenoid), electronics, data acquisition and CLAS12 trigger system, upgraded beam-line and final assembly and Installation of all components of the CLAS12.
1.4.2.1	Construction Hall B Magnet	This summary WBS covers the construction of the CLAS12 Superconducting Magnets: Solenoid and Torus.
1.4.2.1.1	Construction Hall B Magnet Toroidal Magnet	This WBS element includes the 6 flat panels of superconducting coils with polar angle coverage from 5 degrees to 40 degrees and azimuthal acceptance from 50% at 5 degrees to more than 90%at 40 degrees The ∫Bdl > 3 Tm@ 5 degree and about 0.5 Tm at 40 degrees Coil cryostat width front face is about 10 mm.

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1.4.2.1.2	Construction Hall B Magnet Solenoid	This WBS element includes the superconducting solenoid with 5 Tesla central field with aperture of 0.78 m and opening angle of 80 degrees in the forward direction. The field uniformity in the target area is better than10-4 in cylinder 0.07 x 0.03m for polarized target operation. The outer dimensions are diameter of about 2m and length of about 1.8 m. It consists of the main coil and compensating coil to minimize the stray field at the detectors location.
1.4.2.2	Construction Hall B Detectors	This summary WBS covers the construction of the CLAS12 Detectors: Tracking, Calorimetry, Cerenkov, and Time of Flight.
1.4.2.2.1	Construction Hall B Detectors Tracking	This summary WBS covers the angle and momentum determination of charged particles.
1.4.2.2.1.1	Construction Hall B Detectors Tracking Silicon Detector	This WBS element includes the Silicon Vertex Tracker (SVT) that provides tracking information from polar angles 40 - 125 deg with nearly full azimuthal coverage. The SVT will have 33,792 channels and will be located inside a solenoid that has a maximal central field of 5 T. The SVT will consist of a barrel silicon tracker (BST). The BST is designed to have four regions each equipped with two stereo layers. The BST will be made of single-sided sensors. A given module will be two-sided, with opposite stereo angle on each side to gain stereo information, with each module side made from single-sided silicon sensors. The four BST regions will be portioned in 10, 14, 18, and 24 sectors, with 256 channels per sector per side, for 33,792 channels total. The BST is an independent tracking system. This WBS element includes the development and procurement of commercial silicon sensors, sensor probing and acceptance testing, provision of CLASS 10,000 clean room space, procurement of the readout chip, and development of DAQ software and firmware, construction of the backing, cooling, and support structures, and assembly and test of the modules and full detector.
1.4.2.2.1.2	Not Used	Not Used.
1.4.2.2.1.3	Construction Hall B Detectors Tracking Forward Drift Chambers	This WBS element includes the charged particle tracking at 5 - 40 degrees. This is provided by the CLAS12 Forward Drift Chambers which consists of 6 sectors located between the Torus Magnet. Each sector is composed of 3 regions of Drift Chambers 1-2-3. Each region consists of 2 superlayers with 6 layers per superlayer; each layer has 112 wires. The CLAS12 system has a total of 24192 sense wires. This element includes procurement of Endplates, chamber wires, feedthroughs, Crimp Pins, gas system, and High Voltage and signal translator board, and cables. This WBS element includes fixture and frame assembly and the stringing of the chambers, QA and testing.
1.4.2.2.2	Construction Hall B Detectors Calorimetry	This summary WBS covers the construction of the Hall B Detectors Calorimetry.
1.4.2.2.2.1	Not Used	Not Used.
1.4.2.2.2.2	Not Used	Not Used.

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1.4.2.2.2.3	Construction Hall B Detectors Calorimetry Forward Calorimeter	This WBS element includes the preshower detector for separation of high energy photons from pi-zero. It is based on lead scintillator arrangement with 5.8 radiation length thickness and scintillator strips of 4.5 cm width read-out by 4 wavelength shifting fibers embedded in the scintillator strips. Subsequent scintillator layers are arranged at about 120 degrees angle with respect to each other providing stereo readout information. It consists of 6 sectors with 1152 channels (192 channels per sector). This WBS element includes procurement of PMTs, wave-length shifting fibers, scintillator strips, HV dividers and support structure. This WBS element includes provision of clean work space, assembly, QA and testing of the 6 sectors of CLAS12 Pre-Shower Calorimeter.
1.4.2.2.3	Construction Hall B Detectors Time of Flight	This summary WBS covers the construction of the Hall B Detectors Time of Flight.
1.4.2.2.3.1	Construction Hall B Detectors Time of Flight Central TOF	This WBS element includes the short plastic scintillators for timing in central region. The central TOF consists of 48 plastic scintillators symmetrically arranged around the beamline, located inside the aperture of the solenoid magnet. Each scintillator has left and right readout with fast PMTs; there are 96 channels in total. This WBS element includes the procurement of PMTs, scintillator bars, active and passive magnetic shielding, light guides and the support structure. This WBS element also includes provision of clean work space, assembly, QA and testing of the CLAS12 Central TOF.
1.4.2.2.3.2	Construction Hall B Detectors Time of Flight Forward TOF	This WBS element includes the FTOF which will be used to measure the time-of-flight of the charged particles in the polar angle range from 5 degrees to 40 degrees. The system will consist of the current CLAS TOF and a new detector layer to improve timing resolution. The new detector layer will consist of 6 arrays with total of 384 scintillator paddles, each read out by two PMTs. This WBS element includes the procurement of PMTs, scintillator bars, magnetic shielding, light guides and the support structure. This WBS element also includes the assembly, QA and testing of the CLAS12 6 sectors of the forward Time-of-Flight system. It also includes the reconfiguration of the existing TOF into two arrays to work with the new arrays. This includes testing of all existing elements and refurbishment of them as needed.
1.4.2.2.4	Construction Hall B Detectors Cerenkov	This summary WBS covers the construction Hall B Detectors Cerenkov.
1.4.2.2.4.1	Construction Hall B Detectors Cerenkov High Threshold CC	This WBS element includes the HTCC which provides detection of electrons in the momentum range >15Mev/c and separates charged pions in momentum range up to 4.9 GeV/c. The detector consists of 48 independent channels covering angular acceptance $5^o < \theta < 35^o$ at $\Delta\varphi = 2\pi$. Carbon Dioxide is used as a radiator at room pressure and temperature. Cerenkov photons are collected by lightweight combined ellipsoidal mirror. The 5” photomultiplier tubes are used for light detection. This WBS element includes production of the ellipsoidal mirrors, procurement of Winston cones, gas windows, photomultiplier tubes, voltage dividers, magnetic shielding, PMT and mirror mounting and the light-tight gas containment vessel. This WBS element also includes the provision of clean CLASS 100,000 work space, assembly, QA and testing of the HTCC detector.
1.4.2.2.4.2	Construction Hall B Detectors Cerenkov Low Threshold CC	This WBS element includes the modification of the Box and the Optics of the existing CLAS Low Threshold Cerenkov (LTCC). This WBS element includes reassembly, QA and testing of the six sectors of the LTCC detector and replacement of such PMTs as necessary.
1.4.2.3	Construction Hall B Computing	This summary WBS covers the construction of Hall B Computing.

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1.4.2.3.1	Construction Hall B Computing Trigger System (Scintillators)	This WBS element includes the construction of the Hall B Computing Trigger System: Level 1 and Level 2 20 Cluster Finder boards (one per VXS crate for the FADC-250s), 18 Segment Finder boards (one per ADB crate for the Drift Chamber readout), central "global" trigger crate including 7 SSP boards, six Level1 Router boards, six Level2 Router boards, Event Processor and Trigger Supervisor, and a trigger distribution crate driving up to 16 links to readout crates.
1.4.2.3.2	Construction Hall B Computing DAQ	This WBS element includes the upgrade of DAQ system to accommodate higher luminosity and data rates New VME controllers with co-processors, computers and network equipment. This WBS element includes developing the firmware and hardware and testing of the DAQ system.
1.4.2.3.3	Construction Hall B Computing Online Computing	This WBS element includes the construction of the Hall B Computing Online Computing: online monitoring New computer/network equipment, new disk storage.
1.4.2.3.4	Construction Hall B Computing Offline Computing	This WBS element includes the construction of the Hall B Computing Offline Computing: data processing.
1.4.2.3.5	Construction Hall B Computing Slow Controls	This WBS element includes the EPICS to accommodate new systems, Torus, Solenoid, SVT, HTCC, FTOF, PCAL, DC.
1.4.2.4	Construction Hall B Electronics	This summary WBS covers the construction of the Hall B Electronics: ADCs, Discriminators, Scalers, High Voltage, Electronic Racks and Crates.
1.4.2.4.1	Construction Hall B Electronics ADC	This WBS element includes the amplitude readout electronics for TOF and calorimeters: 250 16-channel JLAB Flash ADC boards, total number of channels 4000 will be installed in 20 VXS crates.
1.4.2.4.2	Construction Hall B Electronics TDC	This WBS element includes the timing readout electronics for drift chambers, TOF detectors, and calorimeters. It includes 25 existing v1190 128-channel TDCs, 36 existing v1290 and 7 existing V1190N 32-channel TDCs, 126 existing Lecroy 1877 96-channel TDCs. The total number of channels is 12096 in FASTBUS and 3984 in VME 249 16-channel JLAB discriminators installed in 16 VME crates.
1.4.2.4.3	Construction Hall B Electronics Scalers	This WBS element includes the count rates for various systems 17 32-channel scaler boards installed in one VME crate.
1.4.2.4.4	Construction Hall B Electronics High Voltage	This WBS element includes the high voltage systems for calorimeters, time-of-flight arrays, and Cerenkov counters. There are needed 13 24-chanel positive HV boards, 87 24-channel negative HV boards, and 5 16-card HV mainframes.
1.4.2.4.5	Not Used	Not Used.
1.4.2.4.6	Not Used	Not Used.

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1.4.2.4.7	Construction Hall B Electronics Crates, Racks	This WBS element includes the construction of the Hall B electronics crates and racks and uninterruptible power supply. It includes 20 VXS crates for FADCs, 4 VXS crates for SVT readout, 20 VME crates for discriminators, 1 VME crate for scalers. Also included are 18 existing upgraded ADR crates and 6 existing FASTBUS crates.
1.4.2.5	Construction Hall B Beamline	This summary WBS covers the construction of the Hall B Beamline.
1.4.2.5.1	Construction Hall B Beamline Faraday Cup Upgrade	This WBS element includes the construction of the Hall B Beamline Faraday Cup upgrade.
1.4.2.5.2	Construction Hall B Beamline Moller Polarimeter Upgrade	This WBS element includes the modification of the locations of the Moller quads and of the electron detection system to adjust the optics for Moller electron pair detection for beam energies up to 11 GeV.
1.4.2.5.3	Not Used	Not Used.
1.4.2.5.4	Construction Hall B Beamline Components	This WBS element includes the raster magnets, beam pipes, monitors. The raster magnets are used to sweep the electron beam across the polarized target face to avoid non-uniform target polarization. The raster system will be upgraded to accommodate the higher beam energy.
1.4.2.6	Construction Hall B Infrastructure	This summary WBS covers the construction and installation of the Hall B Infrastructure
1.4.2.6.1	Construction Hall B Infrastructure Utilities	Not Used.
1.4.2.6.2	Construction Hall B Infrastructure Mechanical Frames	Not Used.
1.4.2.6.3	Construction Hall B Infrastructure Assembly	Not Used.
1.4.2.6.4	Construction Hall B Infrastructure Installation	This WBS element includes the modification of the cryogenic distribution for new magnets, plumbing for LCW and gas systems, electrical distribution rework, and upgrade HVAC as necessary. This WBS element includes the modification of the Space Frame: cutting Level 2 Deck, adding a level 1 extension for HTCC, reworking L1 track system, moving downstream column and top beam. This WBS element also includes the reinforcement of the FC, modification of the detector supports, and building carts for detectors. This WBS element includes the installation tooling to lift detectors and magnets into position. This WBS element includes the installation of all components of the CLAS12 detector: the forward detector and the central detector. Installation of the forward detector includes installation of the superconducting Torus magnet, six sectors of three regions of drift chambers, six sectors of preshower calorimeter, six sectors of two panels of time-of-flight system, six sectors of low threshold Cerenkov counter. Installation of the central detector includes the installation of the superconducting solenoid magnet, the central time-of-flight system and the barrel silicon vertex tracker and forward silicon tracker. In addition to the installation of the forward and central detector, this WBS element includes also the installation of the high threshold Cerenkov counter located between the central and the forward detectors.

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1.4.2.7	Construction Hall B Magnet	This summary WBS covers the redesign and construction of the CLAS12 Superconducting Magnets: Solenoid and Torus.
1.4.2.7.1	Construction Hall B Magnet Toroidal Magnet New Vendor	This WBS element includes the 6 flat panels of superconducting coils with polar angle coverage from 5 degrees to 40 degrees and azimuthal acceptance from 50% at 5 degrees to more than 90%at 40 degrees The ∫Bdl > 3 Tm@ 5 degree and about 0.5 Tm at 40 degrees Coil cryostat width front face is about 10 mm.
1.4.2.7.2	Construction Hall B Magnet Solenoid New Vendor	This WBS element includes the superconducting solenoid with 5 Tesla central field with aperture of 0.78 m and opening angle of 80 degrees in the forward direction. The field uniformity in the target area is better than10-4 in cylinder 0.07 x 0.03m for polarized target operation. The outer dimensions are diameter of about 2m and length of about 1.8 m. It consists of the main coil and compensating coil to minimize the stray field at the detectors location.
1.4.2.7.3	Construction Hall B Magnet Infrastructure	This WBS is for miscellaneous infrastructure costs needed in support of Jlab costs to set up soldering line, magnet redesign efforts, Jlab factory costs, etc.
1.4.2.7.4	Construction Hall B Torus Cryostat Factory	This summary WBS covers the design, setup and operation of the cryostat factory for the torus coils.
1.4.2.7.4.1	Construction Hall B Torus Cryostat Factory Design & Procedures	This WBS element includes designing all needed fixtures, tables, and tooling and creating and reviewing the needed procedures to operate the cryostat factory, and performing needed tests in support of the procedures.
1.4.2.7.4.2	Construction Hall B Torus Cryostat Factory Prototype	This WBS element includes testing all lifting fixtures and tooling with the coil cases from the prior vendor, installing the fixtures and tooling into the factory area, and performing the assembly of the prototype cryostat module with the prototype coil, and preparing anny needed procedure revisions based on the experience gained.
1.4.2.7.4.3	Construction Hall B Torus Cryostat Factory Production	This WBS element includes operation of the torus cryostat factory to prepare all production cryostats.
1.4.2.7.5	Construction Hall B Torus Magnet Design/Parts	This summary WBS covers final design, certification and issuance of drawings, and procurements of all machined magnet parts needed to manufacture the Torus magnet.
1.4.2.7.5.1	Construction Hall B Torus Magnet Design/Parts	This WBS element includes final design, certification and issuance of drawings, and procurements of all machined magnet parts needed to manufacture the Torus magnet.
1.4.2.7.6	Construction Hall B Torus Cryogenics	This summary WBS covers design and procurements of all aspects of the cryogenics system for the Torus magnet.
1.4.2.7.6.1	Construction Hall B Cryo Distribution Can	This WBS element includesdesign, engineering, preparation of drawings, and procurement of the distribution can for cryogens to be used in the Torus magnet.
1.4.2.7.6.2	Construction Hall B Cryo Control Can	This WBS element includesdesign, engineering, preparation of drawings, and procurement of the control can for cryogens to be used in the Torus magnet.
1.4.2.7.7	Construction Hall B Torus Instrumentation & Controls	This summary WBS covers, for the Torus magnet, the final design, issuances of drawings, procurement of instrumentation items and sensors, and procurement of modules for controls functions, preparation of software and firmware, and system assembly and testing. It includes design and procurements for the magnet protection systems

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1.4.2.7.7.1	Construction Hall B Torus Instrumentation & Controls	This WBS element includes, for the Torus magnet, the final design, issuances of drawings, procurement of instrumentation items and sensors, and procurement of modules for controls functions, preparation of software and firmware, and system assembly and testing. It includes design and procurements for the magnet protection systems
1.4.2.7.8	Construction Hall B Solenoid Magnet Design/Parts	This summary WBS covers final design, certification and issuance of drawings, and procurements of all machined magnet parts needed to manufacture the Solenoid magnet.
1.4.2.7.8.1	Construction Hall B Solenoid Magnet Design/Parts	This WBS element includes final design, certification and issuance of drawings, and procurements of all machined magnet parts needed to manufacture the Solenoid magnet.
1.4.2.7.9	Construction Hall B Solenoid Cryogenics	This summary WBS covers design and procurements of all aspects of the cryogenics system for the Solenoid magnet.
1.4.2.7.9.1	Construction Hall B Solenoid Cryogenics	This WBS element includesdesign, engineering, preparation of drawings, and procurement of the control can for cryogens to be used in the Solenoid magnet together with items needed to lower the cryogen temperature to 4.2K as required by the magnet design.
1.4.2.7.10	Construction Hall B Solenoid Instrumentation & Controls	This summary WBS covers, for the Solenoid magnet, the final design, issuances of drawings, procurement of instrumentation items and sensors, and procurement of modules for controls functions, preparation of software and firmware, and system assembly and testing. It includes design and procurements for the magnet protection systems
1.4.2.7.10.1	Construction Hall B Solenoid Instrumentation & Controls	This WBS element includes, for the Solenoid magnet, the final design, issuances of drawings, procurement of instrumentation items and sensors, and procurement of modules for controls functions, preparation of software and firmware, and system assembly and testing. It includes design and procurements for the magnet protection systems
1.4.2.7.11	Construction Hall B Torus Risk Mitigation	This summary WBS includes actions to mitigate risk during Torus magnet manufacture and includes cold testing at LN2 and LH2 temperatures plus manufacture of spare coils and cryostats.
1.4.2.7.11.1	Construction Hall B Addition FNAL Coils for Torus	This WBS element includes fabrication of two more coil cold masses for the Torus at FNAL, including a prototype with good conductor and a final spare coil cold mass.
1.4.2.7.11.2	Construction Hall B Added Torus Coil Case and Cryostat	This WBS element includes procurement of the added coil cases and cryostats needed to build the spare Torus coils.
1.4.2.7.11.3	Construction Hall B LN2 Testing of Torus Magnet Coils	This WBS element includes facilities and operations to perform LN2 temperature cold tests of each Torus coil cold mass, including the prototype and the spare as wwell as the produciton modules.
1.4.2.7.11.4	Construction Hall B Additional Copper Stabilizer and Conductor Soldering for Torus	This WBS element includes procurement of added copper stabilizer and soldering operations to support preparing the spare Torus coil cold mass.
1.4.2.7.11.5	Construction Hall B Saclay Lhe Testing for Torus Coils	This WBS element includes design, setup, and operation of cold tests at liquid helium temperature using the vacuum cryostats located at CEA Saclay, France, to test the prototype and the spare Torus coil cold masses and study their operation.
1.4.2.7.12	Construction Hall B Solenoid Spare SSC Cable	This summary WBS covers acquisition of spare SSC cable for the Solenoid magnet.
1.4.2.7.12.1	Construction Hall B Solenoid Spare SSC Cable	This WBS element includes acquisition of spare SSC cable for the Solenoid magnet and covers both acquisition of strand if needed and cabling of the strand into SSC outer Dipole cable as required.
1.4.2.7.12.2	Not Used	Not Used

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1.4.2.7.12.3	Not Used	Not Used
1.4.2.7.13	Not Used	Not Used
1.4.2.7.13.1	Not Used	Not Used
1.4.2.7.13.2	Not Used	Not Used
1.4.2.7.13.3	Not Used	Not Used
1.4.3	Construction Hall C	This summary WBS covers the Hall C construction for 12 GeV Upgrade: SHMS magnetic spectrometer with accompanying detectors, electronics, assembly and installation. The SHMS has 5 superconducting magnets with a DQQQD design that will be capable of resolving particles up to 11 Get/c in momentum. This device achieves 4.5 msr, acceptance at bend angles from 5.5 degrees to 40 degrees by using five magnetic elements.
1.4.3.1	Construction Hall C Magnet	This summary WBS covers the construction of 5 superconducting SHMS Magnets: Horizontal Bend (HB) Magnet, Q1 quadrupole magnet, Q2/3 (almost) identical quadrupole magnets, and a large Dipole magnet.
1.4.3.1.1	Construction Hall C HB Magnet	This WBS element includes the 3 degree horizontal bend magnet. The 3 Tesla Horizontal Bend (HB) Dipole magnet, with an effective length of 60 cm, is the first magnet of the SHMS system. It bends all particles up to 11 GeV/c by 3 degrees to allow the SHMS to reach a 5.5 degree scattering angle. This compact cold iron yoke superconducting “C type” magnet uses a relatively high current density superconducting coil to achieve this field in a compact package that permits the small scattering angle without leaking substantial field into the path of the outgoing electron beam.
1.4.3.1.2	Construction Hall C Q1 Quadrupole	This WBS element includes the Q1 quadrupole magnet. Q1 follows the successful design of the High Momentum Spectrometer’s (HMS) Q1, that of an elliptically shaped super ferric yoke, conformal mapped window frame coil, and helium bath cooled coil design. The primary differences between the two designs are in the choice of superconducting cable and slightly increased gradient (15%). A single stack of surplus SSC Rutherford NbTi cable replaces the original four stack copper stabilized conductor used in the HMS’s Q1. The SHMS Q1 will have a warm bore diameter of 400 mm and produce field gradients up to 9.1 T/m.

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1.4.3.1.3	Construction Hall C Q2/3 Quadrupoles	This WBS element includes the Q2/3 quadrupole magnets. This pair of almost identical cos(2Q) quads have a large 60 cm warm bore and 13 T/m gradient. These 5T Quads provide focusing for particles from 1 to 11 GeV/c and have an integral gradient strength of 23.5 (T/m)m. The quadrupole cold mass uses a stainless steel shrink fit force collar, titanium keys and a copper stabilized superconductor consisting of a 36 strand surplus SSC outer cable wave soldered to a copper extruded substrate. This combination provides for a conservative magnet that can be assembled with little or no tooling and a high degree of stability.
1.4.3.1.4	Construction Hall C Dipole Magnet	This WBS element includes the Dipole magnet. This 4.5 T superconducting cos(Q) dipole magnet provides momentum analysis for particles from 1 to 11 GeV/c and has bend strength of 13.5 Tm. The dipole's cold mass uses a stainless steel shrink fit force collar, titanium keys and a copper stabilized super conductor consisting of a 36 strand surplus SSC outer cable wave soldered to a copper extruded substrate. This combination is similar to the Q2/3 quadrupole magnets above and equally provides for a conservative magnet that can be assembled with little or no tooling and has a high degree of stability.
1.4.3.1.5	Construction Hall C Common Magnet Components	This WBS element includes components and associated activities for one or more of the SHMS magnets which are supplied by JLab as opposed to being part of the individual magnet fabrication contracts.
1.4.3.1.6	Hall C Spare Coils	This summary WBS element includes construciton of spare coils, one each for the Q2/Q3 quadrupoles and one for the main Dipole, plus installation if needed.
1.4.3.1.6.1	Construction Hall C Spare Coils	This WBS element includes production of spare coils for the SHMS spectrometer magnets: Main Dipole and Q2/Q3. Includes fabrication subcontract, subcontract management, procurements of materials and supplies, shipping, engineering support, incoming inspection, and quality control.
1.4.3.1.6.2	Installation of Hall C Spare Coils	This WBS element includes storage of the spare coils at Jefferson Lab until/unless it is determined that the coils must be installed in the magnets. If one or more of the coils is needed, this WBS will include all activities, materials, manpower, technical and management oversight, shipping and subcontracts necessary for dismantling the magnet(s), installing the replacement coil(s), refurbishment of the magnet(s) as necessary, reassembling the magnet(s), testing, delivery to JLab, and re-installation of the affected magnet(s) on the SHMS, and acceptance-testing at JLab.
1.4.3.1.6.3	Not Used.	Not Used.
1.4.3.1.7	Not Used.	Not Used.
1.4.3.1.7.1	Not Used.	Not Used.
1.4.3.1.7.2	Not Used.	Not Used.
1.4.3.1.7.3	Not Used.	Not Used.

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1.4.3.2	Construction Hall C Detector	This summary WBS covers the construction of the detector package located in SHMS shield house, consisting of a pair of wire chambers, hodoscopes, two Cerenkov detectors and a shower counter.
1.4.3.2.1	Construction Hall C Detector Wire Chambers	This WBS element includes the wire chambers that provide the tracking information within the SHMS acceptance. The two wire chambers will have 6 sense planes each, with a resolution of 150um, and a wire spacing of 1 cm. These chambers are constructed using the “open plane” technique in which individual wire and cathode (foil) planes are fabricated on a work bench, then stacked up on a rigid frame to make the chamber assembly. This is a copy of existing designs used for SOS and HKS, which use commercially available readout electronics. Scope, apart from the front-end electronics, to be provided as an NSF contribution.
1.4.3.2.2	Construction Hall C Detector Hodoscope (Scintillator Hodoscopes)	This WBS element includes the two pairs of X-Y hodoscopes that will provide the main trigger system for the SHMS detector system. S1x, S1Y, and S2X will be made of “thin” (5 mm), BC408 scintillator elements with long attenuation length; S2Y will consist of relatively “thick” (2.5cm) quartz Cherenkov radiator elements. Standard 12-stage PMTs like the XP2262B will be employed at each side. The 3 scintillator hodoscope planes consist of 12, 14, and 14 bars, respectively, while the quartz detector plane consists of 10 bars. Scope to be provided as an NSF contribution.
1.4.3.2.3	Construction Hall C Detector Noble Gas Cerenkov (Atm Press Cerenkov)	This WBS element includes the 2.5 m long noble gas Cerenkov detector that will provide additional e/pi separation at high momenta. The Cherenkov tank will use the final 3 m of the spectrometer vacuum system as it enters the SHMS detector hut. If in use, an additional vacuum window with the same thickness as the standard exit window would be installed upstream of the Cherenkov counter. The detector will use four mirrors and four 5 inch PMTs.
1.4.3.2.4	Construction Hall C Detector Heavy Gas Cerenkov	This WBS element includes the C4F8O (or C4F10) heavy gas Cerenkov detector will provide e/pi and pi/p separation at moderate momenta. The enclosure is a cylinder of nonmagnetic stainless steel, with the four PMTs located outside, viewing through a 1-cm thick UV-grade fused silica window. Four 5” PMTs will be used, similar to the PMT currently used in Hall B, except with a flat face of fused silica, which allows for flush mating with the quartz window. The mirrors will be thin glass with protective aluminum coating. The particle entrance and exit windows will be made of 20 mil titanium. This activity includes manufacturing drawings, gas system, mirror shipping, assembly and testing. The fabrication of the tank, mirrors, mirror coating plus the procurement of the PMTs and fused silica windows are included under WBS 1.10.3.2.4.

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1.4.3.2.5	Construction Hall C Detector Shower Counter	This WBS element includes the electromagnetic calorimeter to be used for coarse energy determination of electrons (~5%÷√e) and pi/e separation of order 100:1. The detector will use existing radiation-hard lead glass blocks, and consist of a preradiator (26 transverse-oriented 10x10x70cm3 blocks) and a total absorber (224 longitudinal-oriented 9x9x50cm3 blocks from HERMES). The addition of a pre-shower detector from existing SOS blocks, improves the pion rejection by a factor of five. Both detector components also use existing PMTs. Scope of the total absorber to be provided as a foreign contribution.
1.4.3.2.6	Not Used	Not Used.
1.4.3.2.7	Not Used	Not Used.
1.4.3.2.8	Construction Hall C Detector Frame	This WBS element includes the detector frames that will support the wire chambers, hodoscopes, heavy gas Cerenkov and shower counter.
1.4.3.3	Construction Hall C Computing	This summary WBS covers the Counting House online computing.
1.4.3.3.1	Construction Hall C Computing DAQ	This WBS element includes the computing in Counting House for online data taking and slow control monitoring. Scope is for five computers and a file server for the data acquisition system, plus four additional counting house terminals.
1.4.3.3.2	Not Used	Not Used
1.4.3.4	Construction Hall C Electronics	This summary WBS covers electronics and power
1.4.3.4.1	Construction Hall C Fast Electronics	This WBS element includes ADC modules, cabling, VME crates, and effort to install and commission new readout electronics and recuperate existing cables, in particular for the lead-glass shower counter.
1.4.3.4.2	Construction Hall C DC Power Infrastructure	This WBS element includes flexible DC power bus for the spectrometer magnets, and the hardware required to support the bus.
1.4.3.5	Construction Hall C Beamline	This summary WBS covers the upgrade of the existing Moeller and Compton Polarimeters to allow for 11-GeV operation. Upgrade of scattering chamber and downstream beamline to allow for new SHMS operation, and magnetic field mapping of new magnets.
1.4.3.5.1	Construction Hall C Beamline Moeller Polarimeter	This WBS element includes the upgrade of operability of Hall C Moeller and Compton polarimeters to 11 GeV. For the Compton, this requires power cabling of an additional (existing) quadrupole magnet. For the Moeller polarimeter, this requires modifications to the vacuum connections and motion system for the vertical magnet chicane.
1.4.3.5.2	Construction Hall C Beamline Compton Polarimeter	This WBS element includes the upgrade of operability of the Hall-C Compton polarimeter to 11 GeV. This requires modifications to the vacuum connections, the motion system, and the elevation layout of the vertical magnet chicane.

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1.4.3.5.3	Construction Hall C Beamline Mapping and Field Measurement	This WBS element includes the modification of existing (HMS) mapper and data acquisition system to be compatible with field mapping of SHMS quadrupoles, and mapping of eight H-type Hall C Arc dipole magnets required for Arc beam energy measurement.
1.4.3.5.4	Construction Hall C Beamline Scattering Chamber	This WBS element includes the pump, vacuum connections, and windows for scattering chamber to be compatible with both SHMS forward-angle operation and new downstream beam (dump) line.
1.4.3.5.5	Construction Hall C Beamline Beam Pipe and Stands	This WBS element includes the new beam dump line (vacuum) with associated exit windows and beamline stands to allow for SHMS compatibility.
1.4.3.5.6	Not Used	Not Used.
1.4.3.6	Construction Hall C Infrastructure	This summary WBS covers the infrastructure associated with cryogenic, vacuum and remote rotation systems of SHMS magnetic spectrometer. This includes the SHMS carriage that holds the five superconducting magnets, the concrete shield house with detector package inside, and cabling for detectors.
1.4.3.6.1	Not Used	Not Used.
1.4.3.6.2	Construction Hall C Infrastructure Support Structure	This WBS element includes the new carriage (rail system, wheels and support platforms) for SHMS.
1.4.3.6.3	Construction Hall C Infrastructure Shield House	This WBS element includes the new shield house to shield both the SHMS detector package and various critical magnet/detector electronics from electromagnetic radiation in a high-luminosity electron scattering environment. The shield house is made of concrete (with thickness varying up to 2 meters), with inner “linings” of lead and borated materials.
1.4.3.6.4	Construction Hall C Infrastructure Cryogenic System	This WBS element includes the upgrade of the existing G0 cryogenic system for SHMS operations. This includes a relocation of the existing outer wall cryogenics distribution, connecting tubes to existing systems and new SHMS magnet systems, and a new transfer line from the Hall C outer wall cryogenics distribution to SHMS.
1.4.3.6.5	Construction Hall C Infrastructure Vacuum System	This WBS element includes the vacuum system for the SHMS magnetic spectrometer (similar to the existing HMS system). This includes two vacuum pumps, vacuum “bellow” connections between the various magnets, and a slit/collimator system in front of the spectrometer.
1.4.3.6.6	Construction Hall C Infrastructure Cabling	This WBS element includes the labor and construction funds to make and install cabling between present SOS patch panels and new SHMS patch panels within detector hut. This includes both HV, LV and detector signal cables for SHMS.

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1.4.3.6.7	Construction Hall C Infrastructure SOS Pivot Modifications	This WBS element includes the modification of SOS pivot to allow for SHMS pivot connection.
1.4.3.6.8	Construction Hall C Infrastructure Installation	This WBS element includes the installation of all components of SHMS (support structure, magnets, shield house, detector package, cryogenic+vacuum system, new beamline+scattering chamber).
1.5	Construction Hall D	This summary WBS covers the Hall D construction for the 12 GeV Upgrade. The GlueX detector will be housed in a new above-ground experimental hall (Hall D) located at the east end of the CEBAF north linac. A collimated beam of linearly polarized photons (with 40% polarization) of energy 8.5 to 9 GeV will be produced via coherent bremsstrahlung with 12 GeV electrons. This requires a very thin diamond crystal radiator and a 3.5 mm collimator 75m downstream of the radiator to achieve the designed polarization. The GlueX detector uses an existing 2.2 T superconducting solenoid that is currently being refurbished. An existing 2800-element lead-glass electromagnetic calorimeter for detecting photons will be reconfigured to match the downstream aperture of the solenoid. Immediately upstream is located a scintillator hodoscope for triggering and for use in time-of-flight (TOF) measurements. The barrel calorimeter, which lines the inside of the solenoid and consists of alternating layers of lead and scintillating fibers bonded together with optical epoxy, will provide position and energy measurement for photons and flight time information for charged particles. A start counter will surround the 30 cm long liquid hydrogen target. This counter will be surrounded by cylindrical straw-tube drift-chambers, which will fill the region between the target and the barrel calorimeter. Planar drift chambers will be placed inside the solenoid downstream of the target to provide accurate track reconstruction for charged particles going in the forward direction. This detector configuration has close to a 4π hermeticity and momentum/energy and position information for charged particles and photons produced from incoming 9 GeV photons. In particular, the geometrical acceptance of the detector for final state particles is typically above 95% and is quite uniform over the detector.

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1.5.1	Construction Hall D Solenoid	This WBS element includes the complete yoke modifications to the solenoid, and moving and assembly of the solenoid in Hall D. The solenoid is the magnetic element selected to provide momentum analysis in the tracking chambers. The solenoid is a 73-inch warm bore super conducting (SC) device that produces a nominal maximum central field of 2.2 Tesla at 1800 Amps. The magnet is 195 inches long and weighs approximately 300 tons. The solenoid was originally designed in 1970 as the Large Acceptance Solenoid Spectrometer (LASS) at SLAC and was subsequently used as the MEGA spectrometer at Los Alamos National Lab (LANL). The solenoid was designed as a highly reliable cryogenically stabilized superconducting magnet. The typical field quality of the solenoid (dB/B ~ 1%) is consistent with the requirements for momentum resolution. The design work needed to rearrange the yoke magnetic geometry and to reduce the external fields substantially is not in the scope of this WBS. The construction modifications entail filling the yoke slots and adding steel at the end to reduce yoke saturation and the escape of internal fields, thus reducing the external fields by creating a symmetric yoke with a large upstream opening. Cladding bars are added to the outside of the yoke to reduce steel saturation and resulting external fields in downstream detectors. The work covered in this WBS includes installing the fully refurbished solenoid in Hall D and testing its cryogenics and field before the detectors (FDC, CDC and BCal) are installed in the magnet bore. The effort to build, install, and commission the cryogenic transfer line and distribution can is included in WBS 1.3.3.2.1.
1.5.2	Construction Hall D Detectors	This summary WBS covers the fabrication and testing of all detectors for the GlueX detector in Hall D. To meet the experimental goals of the experimental program, the detector system is required to fulfill: detector with charge particle identification and detection over a broad angular range, detector with photon detection over a broad angular range, detector with good momentum and energy resolution, electronics fully pipelined, and detector capable of acquiring at least 10^7 tagged photons per second. The WBS covers the fabrication of the tracking detectors (CDC and FDC) as well as the photon detection systems (BCal and FCal) as well as the particle identification detector (ToF). The individual detector systems are described on WBS level 5.
1.5.2.1	Construction Hall D Detectors Tracking	This summary WBS covers the physics program of GlueX that requires the detection of charged particles over a wide range of scattering angles. This is achieved by the two tracking systems, the central drift chamber and the forward tracking chamber. The CDC covers an angular range 6° – 165° and the FDC 1° – 25°. Both detectors sit in the bore of the solenoid.

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1.5.2.1.1	Construction Hall D Detectors Tracking Forward Chambers	This WBS element includes the fabrication and testing of the tracking chambers downstream of the central tracking region for angles less than ~25 degrees. The forward drift chambers (FDCs) include 4 separate packages of disk-shaped horizontal drift chambers to measure the momentum of all charged particles emerging from the target at angles of up to 25° relative to the photon beamline. Each chamber is 1.2 m in diameter and consists of 6 wire planes, each one flanked on either side by cathode planes divided into thin strips. The strips are oriented at ± 75° with respect to the wires and 30° with respect to each other. Neighboring chamber layers will be rotated by 60° with respect to each other to improve track reconstruction decisions on the corresponding left/right ambiguities in the wire planes, therefore improving the overall resolution. The spatial resolution of the FDC is expected to be better than 200 µm. Each wire plane consist of alternating field and sense wires, with a sense to field wire separation of 5 mm and a wire plane to cathode plane separation of 5 mm. The wires that cross through the beamline will be deadened to beam spray out to a radius of 3.5 cm. The nominal design for the cathode planes calls for a strip pitch of 5 mm and a strip-to-strip separation of 1 mm. The strips will lie on a 2 mil thick Kapton backing. The strips themselves will be copper with a thickness of 2 µm. A ground plane is included between neighboring cathode planes to ensure minimal signal cross-talk. The sense wires will be at a positive high voltage, the field wires at a negative high voltage and the cathode planes will be at ground. The number of sense wires on each wire plane is 96 and the number of field wires is 97. Each cathode plane consists of 216 cathode strips. The total number of anode wires per FDC package is 576 and the number of cathode strips per FDC package is 2592. The total number of readout channels for the full FDC system is 12672. Each signal from the FDCs (anodes and cathodes) will be sent to a chamber-mounted charge-sensitive preamplifier that drives a pulse-shaping amplifier. The signals from the anode wires that are above some pre-determined voltage threshold will be discriminated and then digitized by 125 ps LSB resolution F1 TDCs (48ch / module). The signals from the cathodes will be digitized with 125 MHz 12-bit flash ADCs (72 ch /module). The chamber has in total 288 HV channels.

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1.5.2.1.2	Construction Hall D Detectors Tracking Central Chambers	This WBS element includes the fabrication of support structure, procurement of all straws, wires and ancillary equipment, and testing of the tracking chambers covering angles above about 10 degrees (3337 straws and 60 HV channels). The assembly of the straws, stringing of wires, addition of gas and electrical services, and initial operational tests are performed under WBS 1.9.5.2.1.2. The purpose of the Central Drift Chamber (CDC) is to accurately measure (ø, *z*) coordinates along charged-particle tracks. In conjunction with the Forward Drift Chamber, it will be used to reconstruct the momentum vector of each track and the primary and secondary vertices of the event. The momentum resolution is a function of particle momentum and the number of hits in both the CDC and FDC. Monte Carlos studies indicate that an rΦ spatial resolution $\sigma_{r\Phi}$, on the order of 150 μm is sufficient to satisfy the physics goals of the experiment. The z-coordinate is obtained using 6° stereo layers. The CDC also needs to provide dE/dx information sufficient for identifying protons with momentum below 0.5 GeV/c. The chamber is built using 28 layers of 1.6 cm diameter, 100 μm-thick aluminized Kapton, 1.5 m-long straw tubes. The signal is registered using a 20μ diameter gold-plated tungsten wire strung under 55 g of tension. Layers 4, 5, 13 and 14 are +6° stereo while layers 6, 7, 15 and 16 are -6° stereo. Due to the packing of the tubes, the exact channel count depends on the exact specifications of the final chamber, but is presently estimated to be 3337 channels. The signals will be read out using capacitive coupled preamps mounted directly on the upstream end plate of the detector and then fed into 12 bit FADC and digitized at 125 MHz. Due to the 2.2 T magnetic field the maximum drift times will be on the order of 900 ns for a typical gas mixture of 87% Ar and 13% CO2. The number of HV channels is 60, fanned out to the individual 3337 straws.
1.5.2.1.3	Construction Hall D Detectors Tracking Start Counter	This WBS element includes the start counter that will be used in the Level 1 trigger to suppress electromagnetic background. The start counter also provides a start signal for time of flight measurements and to identify the beam pulse associated with the observed event. In order to be independent of particle momenta and trajectories, the start counter is located as close to the target as possible. To be able to identify beam pulses the detector needs a minimal time resolution of 300 ps. The start counter for the Hall D detector system follows a successful design of the Hall B start counter. It is a hodoscope segmented in 40 individual channels and readout with SiPMs. The signals from the SiPMs will be discriminated and then digitized by 62 ps LSB resolution F1 TDCs (32ch / module) and with 250 MHz 12-bit flash ADCs (16 ch /module). Each SiPM will have his individual HV channel.
1.5.2.2	Construction Hall D Calorimetry	This summary WBS covers the fabrication and testing of all detectors to detect energy via calorimeter measurements in the GlueX detector. The physics program of GlueX requires the detection of neutral particles (π0 and photons) over a wide range of scattering angles. This is achieved by the two calorimeter systems, the forward calorimeter and the Barrel Calorimeter. The FCal covers an angular range 1° – 11° and the BCal 12° – 120°. The BCal sits in the bore of the solenoid and the FCal at 625 cm in the forward direction from the beginning of the target.

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1.5.2.2.1	Construction Hall D Calorimetry Barrel Calorimeter	This WBS element includes the fabrication and testing of the barrel calorimeter (BCAL). The purpose of the barrel calorimeter is the detection and energy determination of photons from the decays of the neutral π°, the η and other mesons decaying into photons. Any charged particles that are swept by the magnetic field to fall within its volume, mostly in the momentum range of 0.3 to 1.0 GeV/c, will also be detected. Spatial information can also be extracted from the timing information relative to the two read-out ends of the BCAL and from the information provided by the independent read-out cells in each end. The physical layout of the BCAL is a ring consisting of 48 modules (segments) at an inner radius of 65 cm and an outer radius of 90 cm. Thus, its approximate thickness is 25 cm corresponding to approximately 16 radiation lengths. The nominal length of each module is 390 cm, the total weight of the BCal is 22 metric tons. Each module is constructed with layers of 96-1mm diameter double clad scintillating fiber optic strands (SciFi+IBk-s) embedded on grooved Pb sheets of 0.5 mm thickness. Thus, each module consists of approximately 190 layers of Pb/SciFi and special optical epoxy composite. The Pb: SciFi: Epoxy ratio (by volume) is 37:49:14. The BCal is segmented azimuthally and in depth with a readout based on Silicon Photomultipliers. The signals will be digitized by 250 MHz 12-bit flash ADCs (16 ch /module). The signals from the SiPMs will be discriminated and then digitized by 62 ps LSB resolution F1 TDCs (32ch / module) and with 250 MHz 12-bit flash ADCs (16 ch /module).
1.5.2.2.2	Construction Hall D Calorimetry Forward Calorimeter	This WBS element includes activities at Jefferson Laboratory in support of the fabrication and testing of the calorimetry below 10 degrees (2800 signal channels). These activities include stacking of the calorimeter blocks into their operating configuration and preparation for installation, which is performed under WBS 1.5.6.2. The fabrication and procurement of the lead-glass calorimeter modules, high-voltage divider bases, mechanical supports, magnetic shields, signal cables, monitoring system, and support structure, are included under WBS 1.9.5.2.2.2. The purpose of the forward calorimeter (FCAL) is to detect and measure the energy and position of photons from the decays of π°, the л and other mesons. The detector consists of 2800 lead glass blocks (F80-00) of dimensions 4x4x45 cm3 arranged in a nearly circular stack of radius ~1.2 m. The Cerenkov light from each block is viewed by FEU-84-3 Russian phototubes. The phototube bases are of a Cockcroft-Walton (CW) design, and the phototubes are shielded from external magnetic fields using a combination of soft iron and μ-metal. A 1 GeV photon produces about 800 photoelectrons corresponding to a phototube signal of about 0.5 V and a rise-time of 10 ns. No further amplification is required.
1.5.2.2.3	Not Used	Not Used.

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WBS	Description	Dictionary
1.5.2.3	Construction Hall D Particle ID	This summary WBS covers the fabrication and testing of all detectors for charge particle identification in the GlueX detector.
1.5.2.3.1	Construction Hall D Particle ID Time-of-Flight	This WBS element includes the fabrication and testing of the counters for particle identification by time-of-flight (168 Signal and HV channels). The purpose of the time-of-flight detector (TOF) is to serve as part of the particle identification system in conjunction with a future Cerenkov detector for forward-going charged particles. The goal is to separate π from K for momenta up to 2.5 GeV/c and for the given geometry 95% separation efficiency is achieved at the highest momentum with a time resolution of at least 80 ps. The TOF will use two planes of scintillator bars located immediately upstream of the lead glass detector (LGD), rotated by 90° to each user. The bars will be 252 cm long, 6 cm wide and 2.5 cm thick. Thus the mass presented by the detector immediately before the LGD corresponds to 5.0 cm of scintillating plastic. Each bar apart from the 2 central ones is read out at both ends with a photomultiplier such as (XP2020 from Philips). The 2 central bars of both planes are split in the middle to provide a central hole to allow for the passage of the beam. The total signal and HV channel count is 168. The signals will be discriminated and then digitized by 62 ps LSB resolution F1 TDCs (32ch / module) and with 250 MHz 12-bit flash ADCs (16 ch /module).
1.5.2.3.2	Not Used	Not Used.
1.5.3	Construction Hall D Computing	This summary WBS covers all activities for Hall D concerning the data acquisition, the online monitoring of the detector and its safety systems. The development of the software to reconstruct the acquired events has been removed from the scope of this WBS.
1.5.3.1	Construction Hall D Computing DAQ	This WBS element includes the fabrication and testing of the data acquisition system for Hall D. The Hall D science program requires an LHC-era state of the art data acquisition system, and the architecture is being designed for a flux of 10^8 photons/sec. Although at experiment startup the incident flux will only be 10^7 photons/sec, the architecture must be appropriate for the full flux to avoid a costly redesign. The architecture scales such that components can be added as needed as the flux increases. The DAQ must be a dead-timeless system capable of accepting a 200 kHz trigger rate (at 10^8 incident photons/sec), transporting the resulting 1 GB/sec of data from the front-end detector electronics into builder nodes, building the data into single events, and delivering the events to the Level 3 farm. The rate to mass storage is 100 MB/sec. Finally, the DAQ must deliver a small subset of the events to calibration and monitoring systems.

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WBS	Description	Dictionary
1.5.3.2	Construction Hall D Computing Online Computing	This WBS element includes the online effort related to taking data and writing it to mass storage will be organized, and includes overall responsibility for designing, installing, and maintaining everything related to controlling and running the experiment. This effort includes the experiment network design and installation, counting house and operator environment, integration and customization of the JLab DAQ system, run management and control, developing the slow controls system, and alarms systems.
1.5.3.3	Not Used	Not Used.
1.5.4	Construction Hall D Electronics	This summary WBS covers the electronics that will amplify, discriminate, and digitize raw detector signals storing them for later readout at level 1 trigger rates of 200 kHz without incurring dead time. A pipelined approach is required due to the high trigger rate. The digitized information must be stored for several microseconds while the level 1 trigger is formed. Multiple events must be buffered within the digitizer modules and read or transmitted while the front ends continue to acquire new events. The raw data rate from the detector is about 1 Gbyte / second. A sophisticated timing system is required to synchronize the pipelines in the front-end modules.
1.5.4.1	Construction Hall D Electronics FADC	This WBS element includes the high resolution flash ADCs that are needed to measure energy depositions in the different subdetectors, like ToF, Bcal, and FCal. For the CDC the energy and the timing of the particle are measured with fADCs. Two different fADCs are developed. The first one is a 12-bit 250 MHz fADC (16 channels/ module) and will be used for fast detectors used in the trigger. The second module runs at 125 MHz and has 72 channels/module. This module is used for the CDC and the FDC.
1.5.4.2	Construction Hall D Electronics TDC	This WBS element includes the high resolution time-to-digital converter needed to measure the timing of the different particles in the event. The already existing F1-TDC is adapted to the needs of Hall D. We will have one high resolution (62ps) version with 32 channels / module and one lower resolution one (125ps) with 48 channels / module. The high resolution modules will be used for the BCal, ToF, Start Counter and Tagger hodoscopes. The lower resolution version are used for the FDCs.
1.5.4.3	Construction Hall D Electronics Trigger	This WBS element includes the effort in developing and constructing the Hall D electronics trigger. The level 1 trigger of GlueX will require information on the sum of the energy deposition in the BCal and the FCal and the number of charged tracks in the ToF system. For this 2 special modules to get the energy sum and track count per crate have to be developed. Other modules collect and process trigger data, distribute decisions and synchronize operations.

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1.5.4.4	Construction Hall D Electronics Crates/Racks	This WBS element includes the effort in developing the Hall D electronics crates and racks. To provide all the different electronics modules, the correct power electronic crates are needed. Hall D will use 2 different versions both based on the VME technology, one being of the VME64X type (9 pieces) and one being the VXS type (49 pieces). These crates as well as the HV crates are sitting 3 each in electronic racks, in total 50 racks are needed. These racks also house LV modules, gas systems and other things needed to run the detector.
1.5.4.5	Construction Hall D Electronics Logic, HV	This WBS element includes the high voltage systems for calorimeters, tagger arrays, pair spectrometer arrays, start counter, time-of-flight arrays and drift chambers. There are needed 12 24-channel positive HV boards, 5 24-channel negative HV boards, 2 negative 24-channel HV boards with SVH connectors, and 7 16-card HV mainframes.
1.5.4.6	Construction Hall D Electronics Detector Electronics	This WBS element includes the test fixtures and their operation for the ASIC for the FDC and CDC, the preamplifier cards construction and their associated test system and operation, also for the FDC and CDC, and the high voltage distribution manifold for the CDC.
1.5.4.7	Construction Hall D Electronics Detector Cabling	This WBS element includes cabling for signal, HV or bias, and low voltage supply cabling (where needed) for the tagger hodoscope and microscope, the pair spectrometer, the start counter, the BCAL, FCAL, FDC, CDC and TOF. It includes procurement, labeling and bundling prior to installation.”
1.5.4.8	Construction Hall D Electronics Full Crate Checks	This WBS element includes full operational checks for all fully-loaded and cabled VME, HV and LV crates.
1.5.5	Construction Hall D Beamline	This summary WBS covers the building of components to produce and monitor coherent bremsstrahlung photon beam for Hall D experiments. The purpose of the photon tagging system is to provide a tagged flux of up to 10^8 Hz of linearly polarized photons from coherent bremsstrahlung in a thin, orientated, diamond crystal. The tagging spectrometer is located immediately downstream of the radiator and 75 m upstream of the collimator hut and experimental area Hall D. The energies of photons are determined by tagging the energy-degraded bremsstrahlung electrons in the spectrometer. The photon energy will be determined with fine resolution (less than 0.1% r.m.s. of the incident beam energy, E_0) for a photon energy, E_y , between 70% and 75% of E_0.
1.5.5.1	Construction Hall D Beamline Tagger	This summary WBS covers the construction of the tagger magnet and its spectrometer.
1.5.5.1.1	Construction Hall D Beamline Tagging Magnet	This WBS element includes the tagging system which consists of one quadrupole magnet and one dipole magnet, a vacuum chamber and the associated focal plane detectors. The dipole runs at about 1.5 T. The pole shoe surfaces are, in the present design, part of the vacuum chamber.

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1.5.5.1.2	Construction Hall D Beamline Hodoscope	This WBS element includes the fabrication and testing of the scintillator detectors for the tagging spectrometer. The focal plane detector array is located just outside the vacuum chamber. One set of 140 fixed scintillation counters spans the broad energy range from 25% to 95% of E_0. A second, movable, microscope of 124 narrow channels will be used to accurately measure the photon energies in the energy range 70 to 75% of E_0.
1.5.5.2	Construction Hall D Target	This WBS element includes the effort in developing the Hall D target. The main physics program pursued with the Hall D detector system will be conducted with a low-power liquid hydrogen target. The planned target is 30 cm long and somewhere between 3 and 6 cm in diameter. Such targets normally employ Mylar target cells. The Mylar cell will be mounted on a metal base to provide for liquid entry ports and a reliable means of positioning the cell. The beam enters through a thin window mounted on a reentrant tube at the base of the cell. The target cell is connected to a condenser located upstream of the cell. The maximum power deposited in the target by the beam is 100 mW. The refrigerator for the target is included.
1.5.5.3	Construction Hall D Beamline Components	This WBS element includes the effort in developing the Hall D beamline components. To produce linearly polarized photons, the electron beam is scattered on a very thin diamond radiator. The radiator has to be perfectly aligned using a goniometer. To enhance the linearly polarized coherent bremsstrahlungs peak needed for the GlueX physics program a two stage collimator system is build. These collimators sit 75 m from the thin diamond radiator. The photon flux is measured with pair spectrometer, in which a small fraction of the photons are converted into e+e- pairs which are detected in a detector system after being split by a dipole.
1.5.6	Construction Hall D Infrastructure	This summary WBS covers the assembly of the individual detector components and their installation in the overall detector structure.
1.5.6.1	Construction Hall D Infrastructure Assembly	This WBS element includes the effort for the Hall D infrastructure assembly. Before the detectors can be installed in the solenoid and on the platforms inside Hall D, the individual detector components have to be delivered to JLab. After delivered to JLab the detectors need to be assembled and tested before they can be installed in the Hall.
1.5.6.2	Construction Hall D Infrastructure Installation	This WBS element includes the production of the environment needed to assemble the detector as a whole. This includes the south and north platforms, as well as the service platform for the FDCs. The detectors are installed in the solenoid and afterwards cabled and the first tests are performed.
1.5.6.3	Construction Hall D Infrastructure Cryogenics	This WBS element included initial manufacturing design work needed to provide the solenoid with liquid Helium and distribute it to the 4 coils of the solenoid. All further effort including final manuacturing design, procurement, labor and commissioning has been moved to WBS 1.3.3.2.1. Instrumentation effort remains in 1.5.1.

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1.5.7	Construction Hall D Spare Solenoid	This WBS element constructs a spare solenoid for use in Hall D. It includes a new superconducting coil and cryostat, and such ancillary systems as needed to connect to existing services available at Hall D. Its dimensions accommodate the existing tracking and calorimeter detectors, their support structures, and the target and start counter at the upstream end of the Hall D detector. It develops a magnetic field of some 2 Tesla, with a stronger field in the target area to match to the fixed-target geometry of the experiment.
1.6	Construction Conventional Facilities	This summary WBS covers all the effort to construct new conventional facilities and modify existing conventional facilities in support of the 12 GeV CEBAF Upgrade.
1.6.1	Construction Conventional Facilities Accelerator	This summary WBS covers all the effort to modify existing buildings and utility systems to support CEBAF operations at 12 GeV.
1.6.1.1	Construction Conventional Facilities Accelerator Buildings	This summary WBS covers all the effort to modify existing buildings to house additional equipment for the CEBAF upgrade to 12 GeV.
1.6.1.1.1	Construction Conventional Facilities Accelerator North & South Access Building Additions	This WBS element includes all the effort to modify the existing North and the South Access Buildings (NAB and SAB) to house the new low conductivity water (LCW) equipment and the new power supplies. Building additions will have similar salient features, such as the foundation, superstructure, exterior closure and roofing, as the existing buildings. This WBS element also includes modifications to the power distribution system in the NAB and SAB to provide increased capacity for the additional Accelerator equipment installed as part of the CEBAF upgrade to 12 GeV. Major components include transformers, ductbank, and switchboards. The cost is based on a quantity estimate from the design documents for all components of the modifications.
1.6.1.1.2	Construction Conventional Facilities Accelerator North & South Access LCW Upgrades	This WBS element includes the construction contract oversight and commissioning effort to modify the four existing low conductivity water (LCW) systems to provide increased capacity for the additional Accelerator equipment installed as part of the CEBAF upgrade to 12 GeV. This WBS element also includes the installation of a backup cooling tower cell and pump at each of the North and South Access Service Buildings. The cost is based on a quantity estimate from the design documents for all components of the modifications.
1.6.1.1.3	Construction Conventional Facilities Accelerator Beam Switchyard Service Building Addition	This WBS element includes all the effort to expand the existing power supply room in the Beam Switchyard Service Building to house upgraded power supplies for the beam transport lines to the existing experimental Halls A, B, & C. Includes installation of new raceways from the power supply room to the accelerator tunnel. The cost is based on a quantity estimate from the design documents for all components of the facility modification.
1.6.1.1.4	Construction Conventional Facilities Accelerator Tunnel Air Conditioning	This WBS element includes all the effort to construct an air conditioning system to provide cooling to the tunnel east and west arcs to ensure established conditions in tunnel after magnet power has been secured. Major components include chillers, coils, copper piping, and controls. The cost is based on a quantity estimate from the design documents for all components of the new air conditioning system.

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1.6.1.1.5	Construction Conventional Facilities North and South Linac Service Buildings Air Conditioning Upgrade	This WBS element includes all the effort to construction of an air conditioning system to provide additional cooling to the North and South Linac service buildings to handle the heat generation from the 12 GeV RF zones 22 through 26. Major components include air handling units (AHU), chilled water lateral piping from existing chilled water main to new AHU's ductwork, and controls.
1.6.1.2	Construction Conventional Facilities Sitework	This summary WBS covers all the effort to upgrade the utility distribution systems to support the CEBAF upgrade to 12 GeV.
1.6.1.2.1	Not Used	Not Used.
1.6.1.2.2	Construction Conventional Facilities Sitework Electrical Distribution - N & S Linac	This WBS element includes all the effort to modify the existing electrical distribution system to provide power for the new RF zones to be installed in the North and South Linac Service Buildings and for the new magnet box power supplies to be installed in the West Arc Service Building (W2). Major components include transformers, switchboards, and breakers. The cost is based on a quantity estimate from the design documents for all components to modify the existing electrical distribution system.
1.6.1.2.3	Not Used	Not Used.
1.6.1.2.4	Not Used	Not Used.
1.6.1.2.5	Not Used	Not Used.
1.6.1.2.6	Not Used	Not Used.
1.6.1.2.7	Not Used	Not Used.
1.6.2	Construction Conventional Facilities CHL	This summary WBS covers all the effort to modify the existing CHL building and utility systems to support the new CHL #2 operations.
1.6.2.1	Construction Conventional Facilities CHL Building Addition	This WBS element includes all the effort to modify the existing CHL building to house the new compressors for CHL #2. Building addition will have similar salient features, such as the foundation, superstructure, exterior closure and roofing, as the existing building. The cost is based on a quantity estimate from the design documents for all components of the facility modification.
1.6.2.2	Construction Conventional Facilities CHL Sitework	This WBS includes all the effort to upgrade the existing electrical distribution system to provide power for the new compressors for CHL #2. Major components of the electrical work include new transformers, switchgear, and breakers. It also includes all the effort to construct an industrial cooling water (ICW) system to provide cooling water for the new compressors for CHL #2. Major components of the ICW system include cooling towers, pumps, and controls. The cost is based on a quantity estimate from the design documents for all components of the upgraded electrical distribution and the new ICW system.
1.6.3	Construction Conventional Facilities Hall D	This summary WBS covers all the effort to construct new conventional facilities to house the Hall D experimental equipment including the beam transport line and to support operations of Experimental Hall D. Referred to as the Hall D Complex.

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WBS	Description	Dictionary
1.6.3.1	Not Used	Not Used.
1.6.3.2	Not Used	Not Used.
1.6.3.3	Construction Conventional Facilities Hall D Complex	This summary WBS covers all the effort to construct new conventional facilities to house the Hall D experimental equipment including the beam transport line and to support operations of Experimental Hall D. Referred to as the Hall D Complex.
1.6.3.3.1	Construction Conventional Facilities Hall D Complex Phase I	This WBS element is all the effort to construct phase 1 of the Hall D Complex. Phase 1 includes a new experimental hall (Hall D), the foundation of a Counting House, and the associated site preparation and utility work. Hall D will house the new GlueX experimental equipment and is a non-occupied space except for maintenance activities on the experimental equipment and the building systems. The Counting House will provide space for a control room, users, and support functions. The cost is based on a quantity estimate from the design documents for all components of the new facility.
1.6.3.3.2	Construction Conventional Facilities Hall D Complex Phase 2	This WBS element is all the effort to construct phase 2 of the Hall D Complex. Phase 2 includes construction of the remaining portion of the Counting House, Tagger Area, Service Building, Cryo Plant Building, and the associated site preparation and utility work. The Tagger Area is a widen section of an underground tunnel at the east end of the new tunnel extension and will house the Tagger magnet, electron beam dump, and associated equipment. The Service Building will house the low conductivity water (LCW) and chilled water (CW) equipment and the power supplies to support the new experimental hall operations. The Cryo Plant Building will house the cryogenics plant that will provide cryogenics to the solenoid in the new experimental hall. The cryogenic equipment is not part of this WBS. The Tagger Area, Service Building, and Cryo Plant Building are all non-occupied spaces except for maintenance activities on the experimental equipment and the building systems. The cost is based on a quantity estimate from the design documents for all components of the new facility.
1.6.3.3.3	Construction Conventional Facilities Hall D Complex Phase 3	This WBS element is all the effort to construct phase 3 of the Hall D Complex. Phase 3 includes connection to the existing underground accelerator tunnel with a new tunnel extension to the Tagger Area and the associated site preparation and utility work. The new tunnel extension will house the new beam transport line to the new experimental hall and connect to the existing northeast stub of the underground accelerator tunnel. The tunnel extension is a non-occupied space except for maintenance activities on the experimental equipment and the building systems. The cost is based on a quantity estimate from the design documents for all components of the facility extension.
1.7	Construction Project Management	This summary WBS covers the management services required for the execution of the construction upgrade plan and schedule.
1.7.1	Construction Project Management Project Office	This WBS element includes the project management for the construction phase of the upgrade project: Project Manager at 80%, Deputy Project Manager, Technical Lead, three Associate Project Managers, Safety Manager, Safety Inspector, Integration Engineer, Accelerator Work Coordinator and three administration support staff.

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1.7.2	Construction Project Management & Integration Office	This WBS element includes the level of effort activity of the project management and integration office for the construction phase of the upgrade project. Costs for this activity have been moved off the project.
1.8	Pre-Ops	This summary WBS covers the pre-operations phase, including both “hot checkout” periods and commissioning with beam periods. Hot checkout periods involve the last stages of checkout of all devices related to beam delivery and associated diagnostics, and is typically done just before accelerator/Hall close-up for beam delivery.
1.8.1	Accelerator Pre-Ops	This summary WBS covers the hot checkout and beam commissioning of the accelerator.
1.8.1.1	Accelerator Pre-Ops Beam Commissioning	This WBS element includes hot check and commissioning of the accelerator for Milestone CD-4A deliverables. It also includes operation of the accelerator in support of the Milestone CD-4B physics deliverables.
1.8.1.2	Accelerator Pre-Ops Utilities	This WBS element includes the utilities required for the hot check and commissioning of the accelerator.
1.8.1.3	Accelerator Systems Checkout & Commissioning	This WBS covers the checkout and commissioning of individual Accelerator systems prior to full integrated checkout and eventual beam commissioning.
1.8.1.3.1	Cryomodule Pre-Ops	This WBS element covers cryomodule powered checkout and commissioning.
1.8.1.3.1.1	Not Used	Not Used
1.8.1.3.1.2	Not Used	Not Used
1.8.1.3.1.3	Not Used	Not Used
1.8.1.3.1.4	Not Used	Not Used
1.8.1.3.1.5	Cryomodules In-Tunnel Checkout	This WBS element includes the in-tunnel checkout for each individual cryomodule.
1.8.1.3.2	Power Pre-Ops Checkout	This WBS element covers Power powered checkout and commissioning.
1.8.1.3.2.1	RF Pre-Ops Checkout	This WBS element covers RF powered checkout and commissioning for individual zones.
1.8.1.3.2.2	Power Supply	This WBS covers the testing of the magnet system box power supplies, integration, inspection, and testing of the box PS and the Trim PS (Insallation)

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1.8.1.3.2.2.1	Power Supply Testing	This WBS covers the testing of the magnet system box power supplies, with dummy load. Testing Arc 1 and Hall A PS w/Dummy load. Also includes placing, connecting and check-out of magnet system box power supplies.
1.8.1.3.2.2.2	Not Used	
1.8.1.3.2.2.3	Not Used	
1.8.1.3.2.2.4	Power Supply Integrated Testing	This summary WBS covers the integration, inspection, and testing of the box PS and the Trim PS (Insallation).
1.8.1.3.3	Cryogenics Pre-Ops Checkout	This WBS element covers Cryogenics standalone powered checkout and commissioning.
1.8.1.3.3.1	CHL2 Pre-Ops Checkout	This WBS element covers CHL2 standalone powered checkout and commissioning.
1.8.1.3.3.2	Hall D Cryogenics Pre-Ops Checkout	This WBS element covers Hall D Cryogenics standalone powered checkout and commissioning.
1.8.1.3.5	Extraction Pre-Ops	This summary WBS covers the system testing for Resonance Control
1.8.1.3.5.1	Not Used	Not Used
1.8.1.3.5.2	Not Used	Not Used
1.8.1.3.5.3	Extraction System Testing Resonance Control	This WBS element covers the system testing for Resonance Control
1.8.1.4		
1.8.1.4.1		
1.8.2	Hall Pre-Ops	This summary WBS covers the final checkout and beam commissioning of Halls A, B, C, and D.
1.8.2.1	Hall A Checkout & Beam Commissioning	This WBS element includes the final checkout and beam commissioning of the beam delivery systems, Hall beamline diagnostic devices, and new detector systems for Hall A.
1.8.1.2.X	Hall A Commissioning with Beam	This WBS element includes the final checkout and beam commissioning of the beam delivery systems, Hall beamline diagnostic devices, and new detector systems for Hall A.

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1.8.2.2	Hall B Checkout & Beam Commissioning	This WBS element includes the final checkout and beam commissioning of the beam delivery systems, Hall beamline diagnostic devices, and new detector systems for Hall B.
1.8.2.2.X	Hall B Commissioning with Beam	This WBS element includes the final checkout and beam commissioning of the beam delivery systems, Hall beamline diagnostic devices, and new detector systems for Hall B.
1.8.2.2.1	Not Used	Not Used
1.8.2.2.2	Not Used	Not Used
1.8.2.2.3	Hall B Trigger, DAQ and Online Software Checkout	This WBS element includes the final checkout of trigger boards, DAQ elements and Online software for Hall B.
1.8.2.2.4	Not Used	Not Used
1.8.2.2.5	Not Used	Not Used
1.8.2.2.6	Torus Operational & Solenoid Acceptance Tests and Mapping	This WBS element includesTorus operational tests and solenoid acceptance tests and mapping.
1.8.2.3	Hall C Beam Commissioning	This WBS element includes the final checkout and beam commissioning of the beam delivery systems, Hall beamline diagnostic devices, and new detector systems for Hall C.
1.8.2.3.X	Hall C Beam Commissioning	This WBS element includes the final checkout and beam commissioning of the beam delivery systems, Hall beamline diagnostic devices, and new detector systems for Hall C.
1.8.2.3.1	HB & Q1 Magnet Testing	This WBS element HB and Q1 magnets acceptance testing, cooldown test, and harmonic coil tests.
1.8.2.3.2	Not Used	Not Used
1.8.2.3.3	Not Used	Not Used
1.8.2.3.4	Not Used	Not Used
1.8.2.3.5	Not Used	Not Used
1.8.2.3.6	Dipole, Q2/Q3 Magnet Testing	This WBS element includes Dipole, Q2 and Q3 magnets acceptance testing, cooldown test, harmonic coil tests and FF tests.
1.8.2.4	Hall D Beam Commissioning	This WBS element includes the final checkout and beam commissioning of the beam delivery systems, Hall beamline diagnostic devices, and new detector systems for Hall D.
1.8.2.4.X	Hall D Beam Commissioning	This WBS element includes the final checkout and beam commissioning of the beam delivery systems, Hall beamline diagnostic devices, and new detector systems for Hall D.
1.8.2.4.1	Hall D Solenoid Commissioning	This WBS element includes final controls test, cooldown and commissioning of the Hall D Solenoid.
1.8.2.4.2	Not Used	Not Used

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1.8.2.4.3	Hall D Online Checkout	This WBS element includes final checkout of the DAQ system and the online software for Hall D
1.8.2.4.3.1	Hall D DAQ Checkout	This WBS element includes final checkout of the DAQ system for Hall D
1.8.2.4.3.2	Hall D Software Checkout	This WBS element includes final checkout of the online software for Hall D
1.8.2.4.4	Hall D Trigger and Electronics Checkout	This WBS element includes final checkout of trigger boards and some front-end electronics boards for Hall D
1.8.2.4.4.1	Not Used	Not Used
1.8.2.4.4.2	Not Used	Not Used
1.8.2.4.4.3	Hall D Trigger Boards - Acceptance Testing	This WBS element includes acceptance tests and checkout of trigger electronics boards for Hall D
1.8.2.4.4.4	Not Used	Not Used
1.8.2.4.4.5	Not Used	Not Used
1.8.2.4.4.6	Hall D Detector Electronics Boards Checkout	This WBS element includes checkout of some of the front-end electronics boards for Hall D.
1.8.2.4.5	Hall D Beamline Components	This summary WBS includes checking operatons for all beamline components
1.8.2.4.5.1	Not Used	Not Used
1.8.2.4.5.2	Not Used	Not Used
1.8.2.4.5.3	Hall D Beamline Component Testing	This WBS element includes checking operatons of Goniometer.
1.8.2.4.6	Hall D Installation Testing	This summary WBS covers all Hall D Pre-Ops installation testing.
1.8.2.4.6.1	Not Used	Not Used
1.8.2.4.6.2	Hall D Installation Operation Checks of CDC, FDC	This WBS element includes operational checks of CDC (Inside Solenoid), FDC (Outside Solenoid) and FDC (Inside Solenoid).

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WBS	Description	Dictionary
1.8.3	Pre-Ops Support	This summary WBS covers the management services required for the execution of the pre-ops upgrade plan and schedule.
1.8.3.1	Pre-Ops Support - Project Office	This WBS element includes the project management for the pre-ops phase of the upgrade project: Project Director, Project Manager, Associate Project Managers, and Administration activities.
1.9	12 GeV - Work For Others (WFO)	This WBS element covers use of Work for Others funds to support construction certain elements of the 12 GeV project
1.9.1	Not Used	Not Used.
1.9.1.1	Not Used	Not Used.
1.9.1.2	Not Used	Not Used.
1.9.1.3	Not Used	Not Used.
1.9.1.4	Not Used	Not Used.
1.9.1.5	Not Used	Not Used.
1.9.1.6	Not Used	Not Used.
1.9.2	Not Used	Not Used.
1.9.2.1	Not Used	Not Used.
1.9.2.2	Not Used	Not Used.
1.9.2.3	Not Used	Not Used.
1.9.3	Not Used	Not Used.
1.9.4	Not Used	Not Used.
1.9.5	Hall D - WFO	This WBS element covers use of Work for Others (WFO) funds to support construction of part of the Hall D scope of the Project
1.9.5.1	Hall D Solenoid	This WBS element covers use of WFO funds to support the conceptual design of the Spare Solenoid that is part of the Hall D scope
1.9.5.2	Hall D Detectors	This WBS element covers use of WFO funds to support construction of part of certain detectors that are part of the Hall D scope
1.9.5.2.1	Hall D Tracking	This WBS element covers use of WFO funds to support construction of part of tracking detectors that are part of the Hall D scope

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WBS	Description	Dictionary
1.9.5.2.1.2	Hall D Central Chambers	This WBS element covers use of WFO funds to support construction of part of the straw tube tracking detector that forms the cylindrical tracking detector inside the Hall D solenoid magnet. Effort includes mounting straws in the support structure, stringing all sense wires, and installing supporting infrastructure for the detector. This work is performed by collaborators at Carnegie Mellon University under subcontract. Further technical description of the central chambers is given above under WBS element 1.5.2.1.2.
1.9.5.2.2	Hall D Calorimetry	This WBS element covers calorimeter detectors that are part of the Hall D Scope.
1.9.5.2.2.1	Hall D Barrel Calorimeter	This WBS element covers use of WFO funds to support construction of part of the Barrel Calorimeter for Hall D, specifically part of the optical sensing elements used to read out the light emitted by the scintillating fibers active element of the barrel calorimeter. This work includes 2 shipments of scintillating fiber, support for phases 2-4 of the BCAL construction manager, and matrix construction, machining and shipping for BCAL modules #9-48.
1.9.5.2.2.2	Hall D Forward Calorimeter	This WBS element covers use of WFO funds to support construction of part of the Forward Calorimeter for Hall D, specifically to refurbish the lead-glass detector elements, refurbish the photomultipliers, build the high-voltage and signal-collection bases for the photomultipliers, build and install the mounting structures for the individual detector elements, and prepare the detector elements for installation in the support structure. This work is performed at Indiana University under subcontract. Further technical description of the Forward Calorimeter is given above under WBS element 1.5.2.2.2
1.9.5.2.4	Hall D Detector Support	This WBS element covers use of WFO funds to support preparation and use of space, including clean rooms and assembly areas, to support construction of part of the Forward Drift Chamber of the Hall D scope of the Project.
1.9.6	12 GeV Accel Buildings	This WBS element covers the use of WFO funds for modifications to existing conventional facilities to support the CEBAF upgrade to 12 GeV.
1.9.6.1	12 GeV N&S Access LCW Upgrades	This WBS element covers the use of WFO funds for the construction contract to modify the four existing low conductivity water (LCW) systems to provide increased capacity for the additional Accelerator equipment installed as part of the CEBAF upgrade to 12 GeV. Major components include cooling towers, pumps, piping, and heat exchangers.
1.9.7	12 GeV Infrastructure	This WBS covers the use of WFO funds to support miscellaneous infrastructure costs associated with establishing the Blue Crab Storage Facility.
1.9.7.1	12 GeV Miscellaneous Infrastructure	This WBS covers the use of WFO funds to support miscellaneous infrastructure costs associated with establishing the Blue Crab Storage Facility.
1.10	Non DOE Scope	Scope to be moved to this WBS element as MOAs are developed.
1.10.2	Hall B Non-DOE Scope Detectors	This WBS element covers use of NSF funds to support construction of part of certain detectors that are part of the Hall B scope
1.10.2.2	Hall B Non-DOE Scope Detectors-Calorimeters	This WBS element covers use of NSF-MRI funds to support construction of part of the calorimeter detectors that are part of the Hall B scope
1.10.2.2.3	Activities for CLAS12 PreShower Calorimeter	This WBS element covers use of NSF-MRI funds to support construction of part of the forward Pre-Shower calorimeter detectors that are part of the Hall B scope

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WBS	Description	Dictionary
1.10.2.2.3.1	WaveLengthShifting Fibers	This WBS element covers use of NSF-MRI funds to support procurement and testing of wave-length-shifting fibers (and the glue needed to attach them) which are used as the sensing element
1.10.2.2.3.2	PMT System	This WBS element covers use of NSF-MRI funds to support procurement and testing of photomultiplier tubes and required ancillary systems for the readout of forward Pre-Shower
1.10.2.2.3.2.1	PhotoMultiplier Tubes	This WBS element covers use of NSF-MRI funds to support procurement and testing of photomultiplier tubes for the readout of the CLAS12 Pre-Shower calorimeter. This is accomplished via an NSF-MRI grant to James Madison University and will procure about 960 PMTs
1.10.2.2.3.2.2	Mu-Metal Shields	This WBS element covers use of NSF-MRI funds to support procurement and testing of the mu-metal magnetic-field shields for the PMTs that read out the Pre-Shower calorimeter. This work will be done by an NSF-MRI grant to Ohio University.
1.10.2.2.3.2.3	High Voltage Cables	This WBS element covers use of NSF-MRI funds to support procurement and testing of the high-voltage cables for the PMTs for the Pre-Shower calorimeter. This work will be done by an NSF-MRI grant to Ohio University.
1.10.2.2.3.2.4	Signal Splitters	This WBS element covers use of NSF-MRI funds to support procurement and testing of the signal splitters used to divide, into amplitude and timing channels, the signals from the PMTs that read out the Pre-Shower calorimeter. This work will be done by an NSF-MRI grant to Norfolk State University.
1.10.2.2.3.2.5	Electronics Cables	This WBS element covers use of NSF-MRI funds to support procurement and testing of the electronics cables needed to interconnect the signal-processing electronics for the PMTs that read out the Pre-Shower calorimeter. This work will be done by an NSF-MRI grant to Norfolk State University.
1.10.3	Hall C Non-DOE Funded Detectors	Hall C Non-DOE Funded Detectors
1.10.3.2	Hall C Non-DOE Funded Detectors Cerenkov Counters	
1.10.3.2.4	Hall C Non-DOE Funded Detectors Heavy Gas Cerenkov Counter	This WBS element includes the C4F8O (or C4F10) heavy gas Cerenkov detector will provide e/pi and pi/p separation at moderate momenta. The enclosure is a cylinder of nonmagnetic stainless steel, with the four PMTs located outside, viewing through a 1-cm thick UV-grade fused silica, which allows for flush mating with the quartz window. The mirrors will be thin glass with protective aluminum coating. The particle entrance and exit plus the procurement of the PMTs and fused silica windows are included under WBS 1.10.3.2.4. All other activities that are part of the Heavy Gas Cerenkov are included under 1.4.3.2.4.