Appendix A
Scope of Work of Ansys LS-DYNA, Ansys Mechanical Enterprise, and Engineering Support to Ansys LS-DYNA

1. Scope of work

1.1 Ansys LS-DYNA

a) Supply of Ansys LS-DYNA 32 core, Perpetual License as per the technical specifications in **Appendix- B**

b) Installation of the Ansys LS-DYNA in the hardware specified by BAPL

1.2 Ansys Mechanical Enterprise

Supply of Ansys Mechanical Enterprise (default 4 core) with Ansys HPC pack (8 core parallel), Perpetual Licence as per the technical specifications in **Appendix- C**

b) Installation of the Ansys Mechanical Enterprise in the hardware specified by BAPL

c) Provide training on Ansys Mechanical Enterprise to BAPL and demonstration on workflow process

d) Run benchmark test case relevant for static structural analysis, rigid body dynamics, transient thermal analysis, shock/vibration analysis, to show the software scalability on 64-core workstation

1.3 Engineering Support to Ansys LS-DYNA

Provide training on LS-DYNA to BAPL and demonstration on workflow process

b) Perform validation simulations with LS-DYNA for standard benchmark cases to demonstrate the applicability of the software for reliable prediction of concrete-piercing projectile into reinforced concrete barriers

c) Simulate the penetration of concrete-piercing projectile into reinforced concrete barriers using LS-DYNA software, ensuring accurate prediction of penetration depth, failure patterns, and structural response under high strain-rate impact conditions.

d) Develop a high-fidelity Finite Element (FE) model as per various CAD geometries provided by BAPL, Hyderabad, adhering to all specifications.

e) Prepare the FE setup in LS-PrePost for LS-DYNA simulations, incorporating:

   i. Advanced material models for concrete and rebar with strain-rate sensitivity and damage evolution.

   ii. Contact definitions and failure criteria for realistic penetration behavior.

f) Execute the project on-site at BAPL Hyderabad, with constant interaction and technical reviews with BAPL engineers and managers.

g) Perform simulations using Explicit and Implicit LS-DYNA solvers for penetration and structural response analysis.

h) Debug and troubleshoot all numerical errors during model execution independently.

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Vendor Requirements

1. Minimum 12+ years of hands-on experience in LS-DYNA-based modeling and simulation of geomechanics and impact problems.

b) Proven expertise in:

   i. Concrete modeling and failure prediction.

   ii. Rebar modeling with strain-rate sensitivity and damage data.

   iii. LS-DYNA Explicit & Implicit solvers.

c) Ability to independently debug and resolve numerical issues during simulation runs.

Onsite Engineer Qualifications

1. ANSYS Certified Professional with LS-DYNA certification.

b) M.Tech in Mechanical Engineering or related domain.

c) Minimum 2 years of relevant experience in FE modeling and LS-DYNA simulations.

d) Strong technical skills in:

   i. High-velocity impact and penetration modeling.

   ii. Concrete and rebar material modeling under dynamic loads.

Deliverables

1. FE model and LS-DYNA setup files for penetration analysis.

b) Simulation results including penetration depth, damage pattern, and stress distribution.

c) Comprehensive technical report and final presentation to BAPL technical team.

2. Acceptance

Acceptance is based on inward goods inspection (IGI) at BAPL, Hyderabad and review of performance of the software including demonstration of core scalability.

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Appendix B
Technical Specifications of Ansys LS-DYNA

S. No.	Technical specifications
1.	**Software tools**
	1. Non-Linear dynamics 2. Coupled rigid body dynamics 3. Quasi-static simulations 4. Normal modes 5. Linear and Non-Linear statics 6. Eigen value analysis 7. Thermal analysis 8. Fluid analysis 9. Eulerian capabilities 10. Arbitrary Lagrangian Eulerian (ALE) 11. Fluid structure interactions 12. Failure analysis 13. Crack propagation 14. Real-time acoustics 15. Multi-physics coupling 16. Structural thermal coupling 17. Adaptive re-meshing 18. Smooth Particle Hydro-dynamics (SPH) 19. Element Free Methods (EFM) 20. X-FEM 21. CESE solver 22. 2-D and 3-D formulations 23. Nastran reader 24. Arbitrary rigid to deformable switching 25. Arbitrary implicit to explicit switching 26. Dynamic relaxation 27. Discrete Element Method (DEM)
2.	**The software have library of following material models with failure criteria**
	1. Metals 2. Ceramics 3. Plastics 4. Visco-elastic 5. Elasto-viscoplastic 6. Glass 7. Foams 8. Fabrics 9. Elastomers and Rubbers 10. Honeycombs 11. Fibre reinforced polymer Composites 12. Concrete and soils 13. High explosives 14. Viscous fluids 15. Biomedical modules 16. User-defined materials

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3.	**The software performs with under-integrated and fully integrated element formulations for the following element types**
	1. Different solid elements 2. 8-node thick shells 3. Different 3- and 4-node shells 4. Beams 5. Welds 6. Discrete Zero Length beams 7. Trusses and cables 8. Nodal masses 9. Lumped inertias 10. Arbitrary Lagrangian Eulerian (ALE) 11. Eulerian elements 12. Element free Galerkin formulations 13. SPH elements 14. Elements for 2D analysis 15. User-defined elements
4.	**The software supports various types contact algorithms as following**
	1. Single surface contact 2. Contact with rigid walls 3. Edge-edge contact 4. Beam-beam contact 5. Eroding contact 6. Contact with CAD surfaces 7. Tied surfaces and Tie-break contact 8. 2-D contact 9. Shell edges tied to shell surfaces 10. Resultant force contact 11. Fluid-structure interfaces 12. Pinball contact 13. Friction models 14. Static and Dynamic 15. Viscous friction 16. Pressure dependent friction 17. User-defined friction models
5.	**The software supports with following rigid body dynamic features**
	1. Rigid bodies 2. Rigid to deformable switching 3. Deformable to rigid switching 4. Joints -Spherical joints -Revolute joints -Cylindrical joints -Translation joints - Locking joints - Motor joints - Pulley and screw joints - Cardan joints - Flexion/torsion joints 5. Contact - Rigid body to deformable body contact - Rigid body to rigid body contact - Multiple discrete elements

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6.	**The software provides the following frequently used dummies and barriers for blast modelling**
	1. Hybrid III dummies 2. SID-IIs dummy 3. P and Q child dummies 4. USSID dummy 5. Eurosid dummy 6. ES-2 dummy 7. ES-2 re dummy 8. BioRID dummy 9. WorldSID dummies 10. Head forms 11. Pedestrian impactors 12. THOR-NT dummy 13. Human models 14. NHTSA barriers 15. NCAP barriers 16. IIHS barrier 17. ECE barriers 18. Euro-NCAP barrier 19. Simple vehicle models 20. Roadside models
7.	**The software provides LS-PREPOST for importing, editing and exporting LS-DYNA models. LS-PREPOST have following features:**
	• <u>General features</u> -Comprehensive support for LS-DYNA input and output files. -Image output formats: PNG, TIFF, JPG, BMP, PCX, PS, PSIMAGE, GIF, VRML2 - Movie output formats: MPEG, AVI, animated GIF, command line interface • <u>Pre-processing features</u> -Other FE input formats -CAD input formats: IGES, Step -CAD geometry data creation and manipulation including cleaning, healing and simplification -Mesh generation, mesh manipulation creation and modification - LS-DYNA entity (keyword) creation - Coordinate systems, sets, parts, masses, CNRBs, boxes, spot welds, SPCs, rigid walls, rivets, initial - Velocity, accelerometers, cross sections • <u>Special applications</u> - Airbag folding - Dummy positioning - Seatbelt fitting - Metal forming - Roller hemming - Model checking • <u>Post-processing features</u>

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	- 3D animation - Time history plots - XY plots - Contour plots - Overlay plots - Vector plots - Fringe plots - Particle visualization - Fluid visualization - DYNAIN file generation - Section Analysis
8.	**Computation**
	Single and Double precision calculation options available Both Shared Memory Processing (SMP) and Massive Parallel Processing (MPP) are available

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Appendix C
Technical Specifications of Ansys Mechanical Enterprise

S. No.	Technical specifications
1.	**Geometric Idealization**
	1. Spring 2. Mass 3. Damper 4. Spar 5. Beam 6. Pipe/elbow 7. Shell-Thin 8. Layered shell-Thin (composites) 9. Shell- Thick (solid shell) 10. Layered shell-Thick (solid shell) (composites) 11. 2D Plane/Axisymmetric 12. 3D solids 13. Layered 3D solids (Composites) 14. Infinite Domain 15. 2.5D 16. Reinforced 17. Coupled Field ROM Element Technology 18. Substructuring/Matrix
2.	**Modelling Capability**
	1. Contact-Linear 2. Contact-Nonlinear 3. Joints 4. Spot Welds 5. Element birth and Death 6. Gasket Elements 7. Rezoning and Adaptive Remeshing 8. Inverse Analysis
3.	**Materials**
	1. Basic Linear Materials (Linear, anisotropic, Temperature dependent) 2. Basic Nonlinear Materials (Hyper, Plasticity, Rate independent, isotropic, concrete) 3. Advanced Nonlinear Materials (Rate independent, Anisotropic, Damage models, Geomechanics materials, Multiphysics) 4. Field dependent 5. Reactive Materials 6. Fracture Mechanics and Crack growth 7. Material Designer 8. GRANTA Materials Data for Simulation
4.	**Composite Materials**
	1. Material Definition 2. Layers Definition 3. Interface Plies 4. Advanced modelling features 5. Variable material data 6. Solid extrusion 7. Lay-up Mapping 8. Draping

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	9. Lay-up exchange Interface 10. Advanced failure criteria library 11. First ply failure 12. Last ply failure 13. delamination
5.	**Structural solver Capability**
	1. Linear Static 2. Nonlinear Static 3. Pre-Stress effects and linear perturbation 4. Nonlinear geometry 5. Bulking-Linear Eigen Value 6. Bulking-Nonlinear Post Bulking behavior 7. Bulking-Nonlinear Post Bulking behavior-arc length 8. Steady state analysis applied to a transient condition 9. Advanced wave loading
6.	**Topology Optimization**
	1. Structural optimization 2. Modal optimization 3. Thermal loads 4. Inertial loads 5. Optimized Design Validation 6. Manufacturing Constraints 7. Stress Constraints 8. Symmetry
7.	**Multi analysis**
	1. Submodeling 2. Data Mapping 3. Multiphysics Data Mapping 4. Initial State 5. Advanced Multi stage 2-D to 3-D analysis
8.	**Vibrations**
	1. Modal 2. Modal-pre-stressed 3. Modal-damped/unsymmetric 4. Transient-mode-superposition 5. Harmonic-mode-superposition 6. Harmonic-full 7. Spectrum 8. Random Vibration 9. Mistuning 10. Rotordynamics 11. Modal Acoustics 12. Harmonic Acoustics
9.	**Nonlinear Transient dynamics**
	1. Rigid Body Mechanisms 2. Rigid Body Mechanisms with CMS L Components for flexible bodies 3. Full transient 4. CMS with sub structuring
10.	**Explicit Dynamics**
	1. FE (Lagrange) Solver 2. Meshless Solvers 3. Implicit-explicit Deformations 4. Implicit-explicit Material states

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	5. Fluid-structure Interaction (FSI) 6. Mass scaling 7. Natural Fragmentation 8. Erosion Based on multiple Criteria
11.	**Durability**
	1. Stress-Life (SN) 2. Strain-Life (EN)
12.	**Wave Hydrodynamics**
	1. Diffraction and Radiation 2. Frequency and time domain motions analysis 3. Moorings, joints and tethers 4. Load Transfer to structural analysis
13.	**Thermal**
	1. Steady state thermal 2. Transient thermal 3. Conduction 4. Convection 5. Radiation to space 6. Radiation: surface-to surface 7. Phase change 8. Thermal analysis of layered shells and solids
14.	**Additional physics**
	1. 1-D thermal-flow 2. 1-D coupled field circuits 3. 1-D electromechanical Transducer 4. MEMS ROM 5. Piezoelectric 6. Piezoresistive 7. Electroelastic 8. Electromagnetic 9. Vibro-Acoustic 10. Electro-Migration 11. Diffusion-Pore-fluid 12. Diffusion-thermal Structural-electric 13. Structural-Thermal-electric- Magnetic
15.	**Optimization**
	1. DesignXlorer Included 2. Parameters 3. Design Point studies 4. Correlation Analysis 5. Design of experiments 6. Sensitivity analysis 7. Goal Driven optimization 8. Six sigma analysis
16.	**Miscellaneous and usability**
	1. ANSYS Spaceclaim 2. ANSYS Customization Suite (ACS) 3. Support ACT Extensions 4. Command Snippet Support

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