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NESM TAG Meeting Notes

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- **Structure surface representation**
  The fluid solver can use a level set, a simplified discrete surface (e.g. triangular facets), the solid mesh directly, or another option for the structure surface representation in the fluid mesh. In any case, for the Initial Offering of Capability (IOC) Sierra/SM plans to send connectivity, coordinates, and velocities at each coupling step, so this choice does not affect the coupling on the Sierra/SM side. And, although the IOC may not need to account for topology changes (e.g. solid element death), the chosen representation should be flexible enough to accommodate this in the future (or be planned to be replaced).

- **Structure-fluid coupling algorithm**
  For the IOC, the coupling from structure to fluid should consist of node-face connectivities, structural nodal coordinates and structural nodal velocities, and the coupling from fluid to structure should consist of pressures at the structural surface integration points on the fluid-structure interaction surface. This will allow a variationally consistent integration of pressure, which though it may not be exact in a discrete setting will be convergent. This will also simplify the coupling algorithm on the solid side by allowing use of a standard pressure boundary condition for load application. Note that displacements may turn out to be preferable to coordinates for certain use cases.

  This scheme may display problems at the interface due to the lack of exact balance of work in a discrete sense. Accuracy loss due to approximate conservation of discrete mass, momentum and energy at the interface introduces risk. The mitigation strategy is to pass topology data from both solvers to a coupler to exactly integrate and enforce work balance across the interface. This would require a significant change to the coupling interface and should be postponed until needed.

- **Coupled time integration scheme**
  The coupled time integration scheme can initially be a simple staggered or concurrent time integration, which we expect to return first-order-in-time convergence. The implementation should be flexible enough to explore higher-order schemes, such as iterative solves, predictor-corrector, staggered solution steps, etc. This flexibility may need to include the ability to pass multiple states of data (or make a decision that each side must store any data it needs).

  Individually the fluid and solid time integration schemes should be verified to be at least second order apart from any coupling.

  The IOC should focus on explicit time integration on the fluid side and be flexible enough to support either implicit or explicit time integration on the solid side. Also, the IOC should implement a fixed time step, lockstep integration scheme for testing and evaluation of the explicit fluid – implicit structure schemes.

- **Coupling data exchange API**
  For the IOC the data to exchange should be connectivity, coordinates, and velocity at the nodes from solid to fluid, and the pressure at each structural surface integration point should be returned from fluid to solid.

- **Portability across platforms and builds**
  For development, testing, and debugging, the entire coupled code suite should build and run on Intel-OpenMPI, Intel-IntelMPI, and GCC-OpenMPI platforms. The Carderock, Weidlinger, and Sierra teams will work together to maintain portability to these platforms.

- **Testing and verification**
  All newly written routines should be unit tested, with > 90% unit test line coverage as the goal for the Carderock, Weidlinger, and Sierra development teams.

  All capabilities should be regression tested in an automated testing regime, ideally with nightly runs of the entire suite. Performance testing should also be conducted regularly and automated if possible. The performance of the coupled capabilities should be on par with the previous production coupled capability.

  A number of candidate verification problems were identified at the TAG meeting. In particular: piston problem, rotated piston problem, angled plunger piston problem, closed control volume force balance, constant pressure sphere problem. It was noted that more problems are needed, and Professor Farhat has a paper in progress that may have a good coupled verification problem with an analytic solution.