Fluid-structure interactions are among the most important considerations when designing complex engineering systems such as aircraft, spacecraft, turbine blades, Formula 1 cars, and underwater vessels, to name only a few. They are also important for the analysis of aneurysms in large arteries and artificial heart valves. They can significantly affect performance and/or structural integrity. For several decades, attention has focused almost exclusively on the linear subclass of such interactions, or on their linearization for stability and control applications. A well-known example in the first case is the theory of elasto-acoustics that is used today for underwater acoustics and imaging. A most notable example in the second case is the linear theory of aeroelasticity that continues to dominate flutter analysis in the aeronautics industry. However, many fluid-structure interactions are nonlinear, and some are highly nonlinear. In the past, these have been dealt with using tests, or have been simply avoided or ignored. Today, the situation has begun to change, as highly nonlinear fluid-structure interactions have become of the utmost importance for the design of future aircraft, advanced spacecraft, and next-generation underwater systems. This is the case, for example, for the N+3 aircraft concept based on a strut-braced wing, NASA’s new low density supersonic decelerators, and currently envisioned underwater vessels that feature a larger than ever number of implodable volumes. Furthermore, for many reasons ranging from safety to feasibility, there is currently a strong need to predict such highly nonlinear interactions numerically. Unfortunately, because of the aforementioned previous trends, the numerical simulation of highly nonlinear fluid-structure interaction problems is currently at a state where it is fraught with computational challenges. To this effect, this lecture will first overview this renaissance of fluid-structure interactions, then present a unified computational framework for their numerical prediction. It will highlight the recent impact of this framework on the design of micro air vehicles with flexible flapping wings, the prediction of the vertical tail buffeting of fighter jets at high angles of attack, the understanding of parachute inflation dynamics, the aeroelastic tailoring of Formula 1 cars, and the failure analysis of submerged implodable volumes.
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