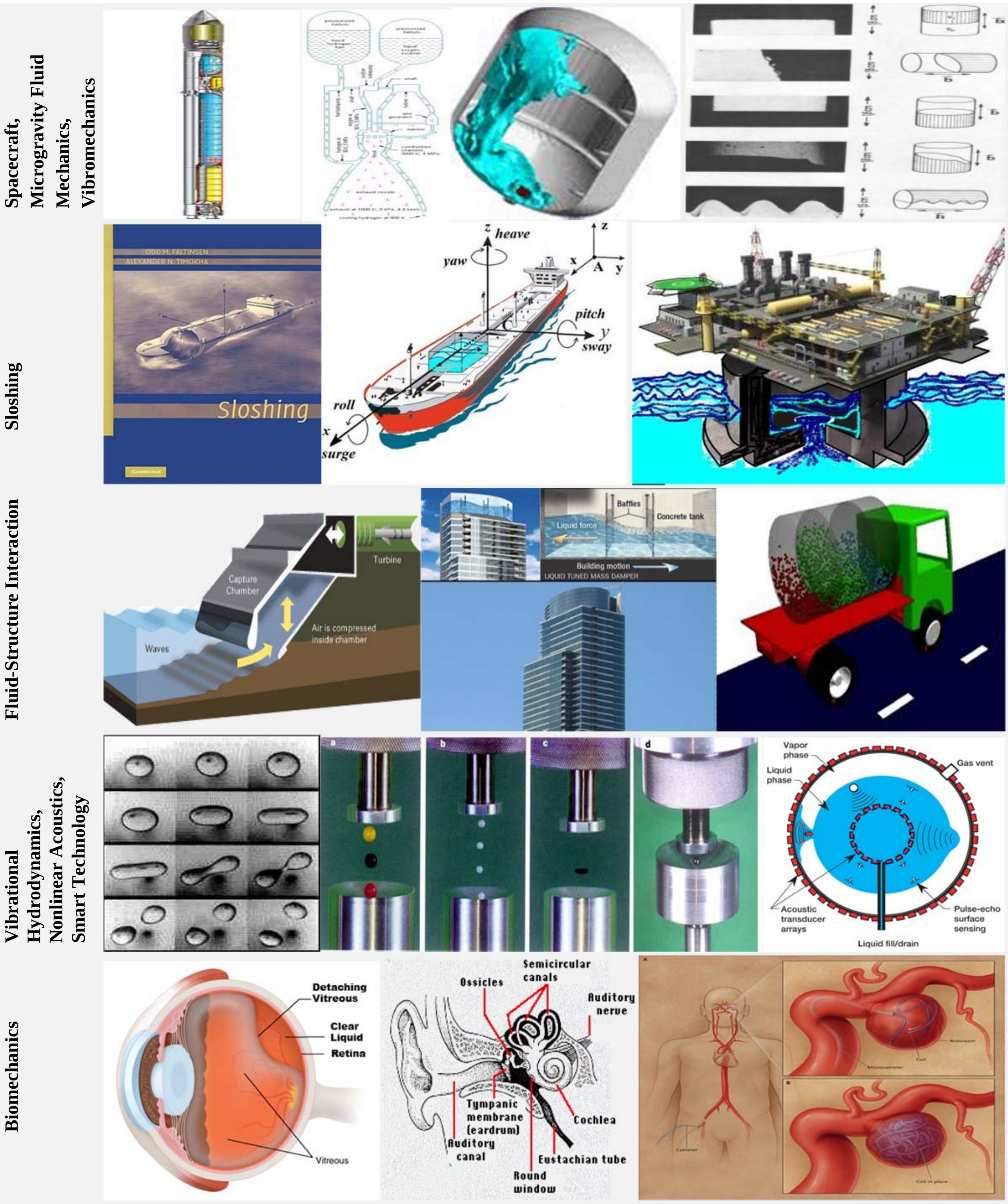
«The free-surface motion”

The following <u>markers</u> identify applications of the former and current research interests:



Specifically, all the considered free-surface [interface] problems are of the *hyperbolic* type and deal with *strongly nonlinear wave motions* relative to static or quasi-static (averaged, mean, etc.) shapes.

The *practical tasks* consist of classifying all the possible *nonlinear* dynamic *regimes* (steady-state and transient) and to study the ***stability*** of these regimes. Because the steady-state solution is typically *not unique,* traditional numerical schemes with spatial-and-time discretization (scientific computing, CFD) fail to solve the practical tasks. Analytical and semi-analytical approximate methods (e.g., multimodal method for sloshing) are required to reduce the original nonlinear problems to *simpler mathematical objects* which admit rigorous mathematical analysis and well-justified numerical solutions.

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Research ideology consists therefore of making the *three steps*:

Optionally (exclusively, for new practical problems), the *first step* implies activities on mathematical *modeling* whose goal is, based on physical principles, to formulate the free-surface [interface] problem which describes the studied interfacial dynamic processes.

Using apparatus of *analytical* applied mathematics, the *second step* should find a way for reducing the already formulated free-surface problem to an approximate simplified mathematical object. Normally, the free-surface problem can be interpreted as a mechanical system with an infinite number of degrees of freedom and, therefore, we are able to get:

(i) a variational formulation following from the analytical mechanics principles (e.g., Hamiltonian formulation),
(ii) a selection of generalized coordinates associated with particular approximate solutions (following, e.g., from linearized statement),
(iii) a set of asymptotic methods to select the leading generalized coordinates.

Of course, *“devil sits in details”*, but getting a simplification is a quite realistic task!

An example is the nonlinear modal equations derived for liquid sloshing problems. They reduce the original free-surface problem to a finite-dimensional system of nonlinear ordinary differential equations.

Another example is for the so-called vibroequilibria occurring due to high-frequency tank vibration. For this case, the original free-surface problem, formulated for *compressible* liquids and gas, can be reduced to a rather simple free-surface problem for an artificial *incompressible* liquid but with an extra quasi-potential in the dynamic boundary condition reflecting an averaged energetic effect of the vibration.

Finally, the *third* step implies pure mathematical and numerical studies of the simplified mathematical objects pursuing a selection of the dynamic regimes and studying their stability.

<u>Historical</u> aspects vs. the markers:

	The problems associated with marker (A) come from interests in microgravity hydrodynamics (1984-1997), nonlinear acoustics (from 1987) and vibrational mechanics (form 1989). Roughly speaking, one can say that these problems were considered as objects of the fluid dynamics[1] (steps 1 and 2) in PhD Thesis (1988), but mathematical and numerical results (steps 2 and 3) were done in DSc [Habilitation] Thesis (1993). The problems related to marker (A) are characterized by nonhomogeneous conditions on the *contact* surface between liquid and the carrying structure. New marker (D) denotes hydrodynamic problems appearing in the *contactless* technology. For (D), steps 2 and 3 should be made.
	Markers (B) and (C) deal with free-surface problems of current interests caused by the CeSOS objectives and activities of the former and new DFG projects[2]. These are associated with (i) sloshing in ship and land-based tanks, (ii) analytical methods for the tuned liquid damper with a perforated screen (steps 2 and 3), (iii) ocean platforms (internal and external flows), moonpools (step 3). The novel directions are (a) the wave energy associated with Oscillating Water Column (OWC) [steps 2 and 3] and (ii) sloshing of a cryogenic liquid (Liquefied Natural Gas, LNG) accounting for physical processes occurring on liquid-vapor interface [steps 1-3].
	Marker (E) is used for biomechanical free-surface problems. It suggests dedicated activities in mathematical modeling, physical and mechanical analysis of biological hyper-elastic structures encapsulating a liquid (step 1). An interdisciplinary cooperation is assumed. One should formulate the corresponding free-boundary problems and find analytical approaches to get simplified semi-analytical statements (step 2).

[1] In 80’s, caused by practical interest of the Design Office “Salut” (famous engineering bureau of the former Soviet Union dealing with the orbital stations) in new technology employing the acoustic methods for control of a liquid in the microgravity. Analogous USA Programs are dated of 90’s.

[2] During 13 years (1997-2010), collaboration with German colleagues was supported by four continuing DFG projects. New activities in engineering mathematics (civil engineering) are announced in new DFG-project “*Ingenieurmathematik für Sloshing-Probleme im Zusammenhang mit der Erzeugung von Wellenenergie, der Sicherheit von Bauwerken sowie der Speicherung/Transport von Containern*“ that has been submitted to the DFG.