NATIONAL TECHNICAL UNIVERSITY of ATHENS, GREECE
SCHOOL of MECHANICAL ENGINEERING / HYDRAULIC TURBOMACHINES LAB.

Numerical modelling of fish passage and flow interaction in a hydroturbine

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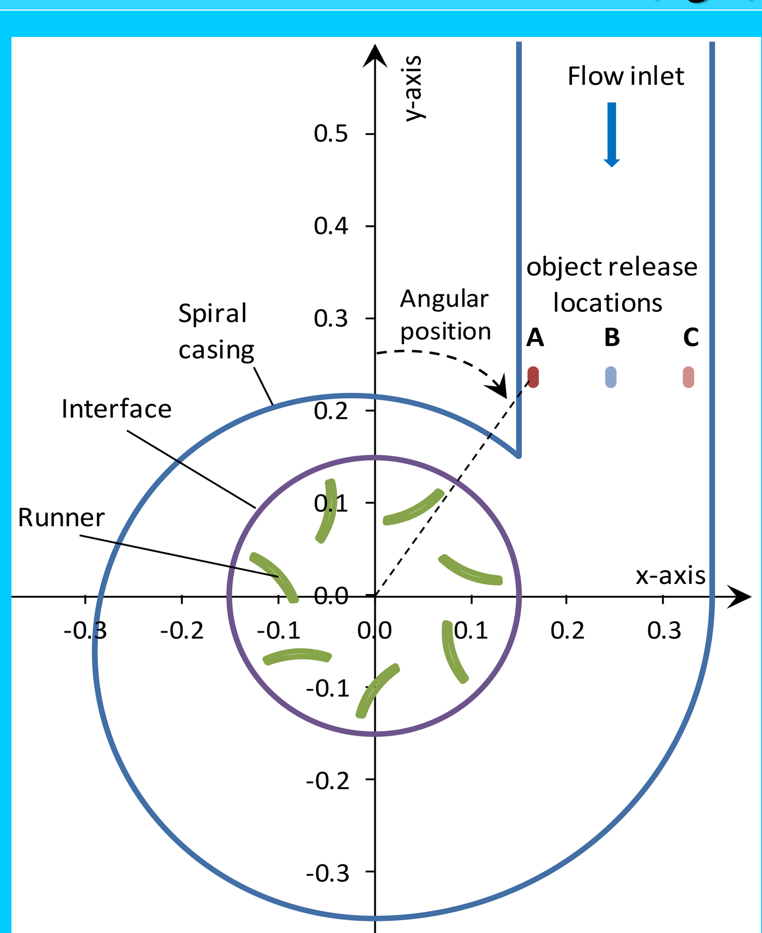
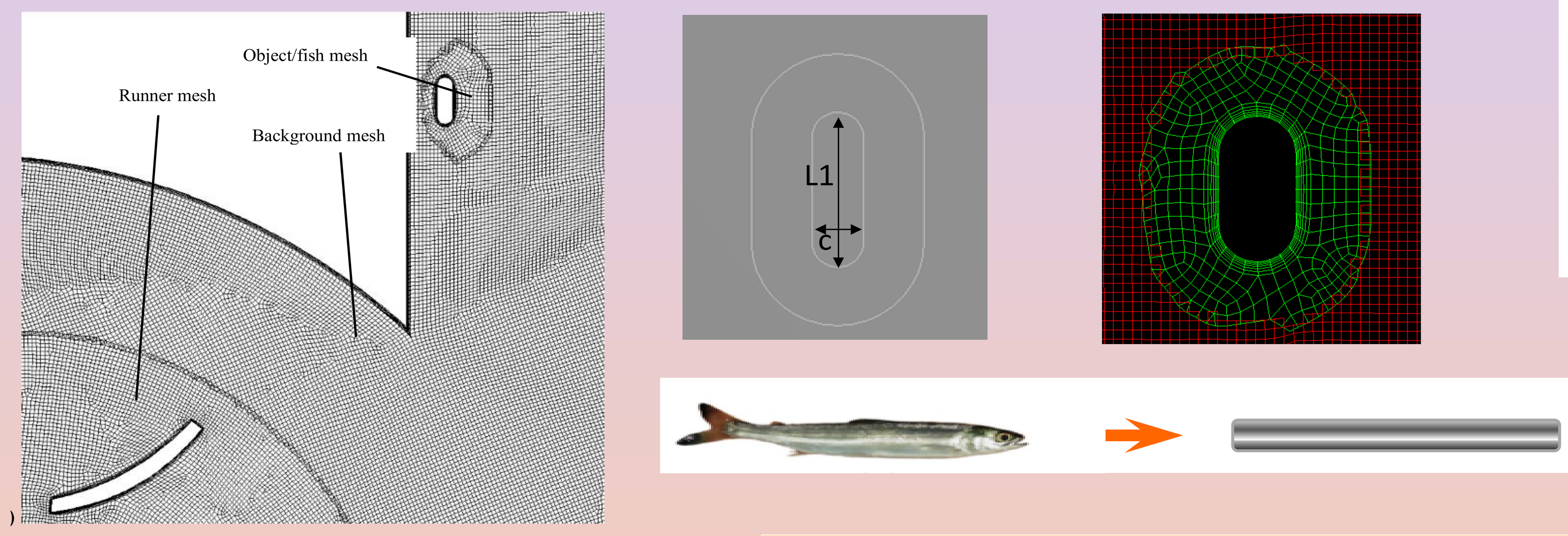
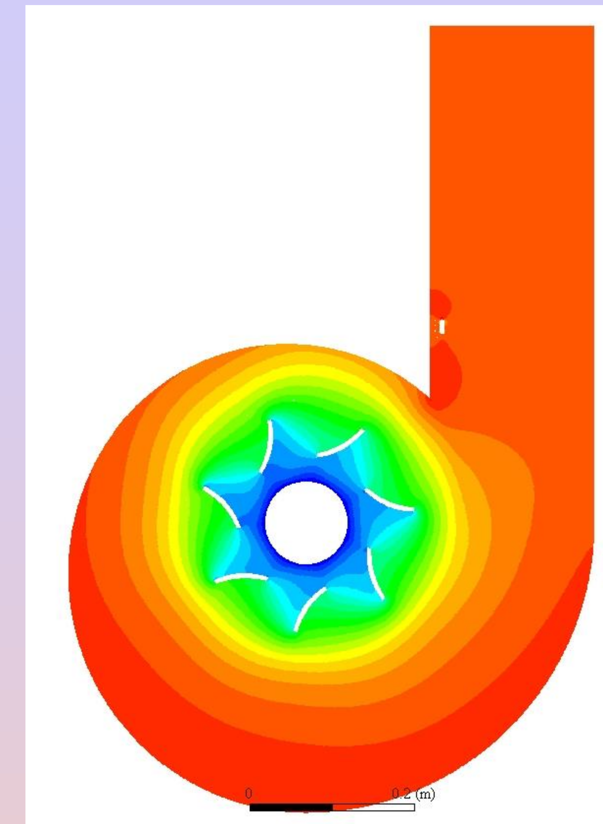
Computational domain (below) and details of the numerical meshes (right)



Fish motion simulation - A. Overset mesh technique

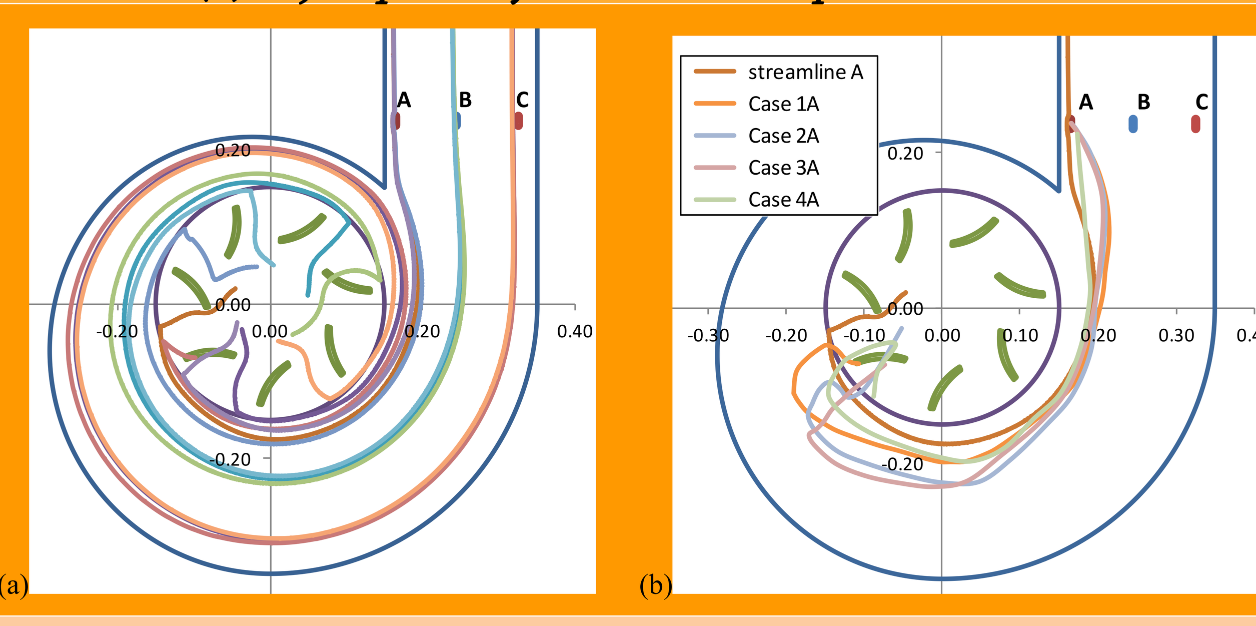
- Solve RANS equations on a background mesh in a simplified, 2D reaction turbine domain.
- Individual component meshes are overlain: For the runner and for the object/fish.
- Update location and active background cells as the object moves.
- Exchange information between meshes by interpolation
- A fish is modelled as a rectangular rigid object (various aspect ratios)





RANS SOLUTION
(Pressure field)

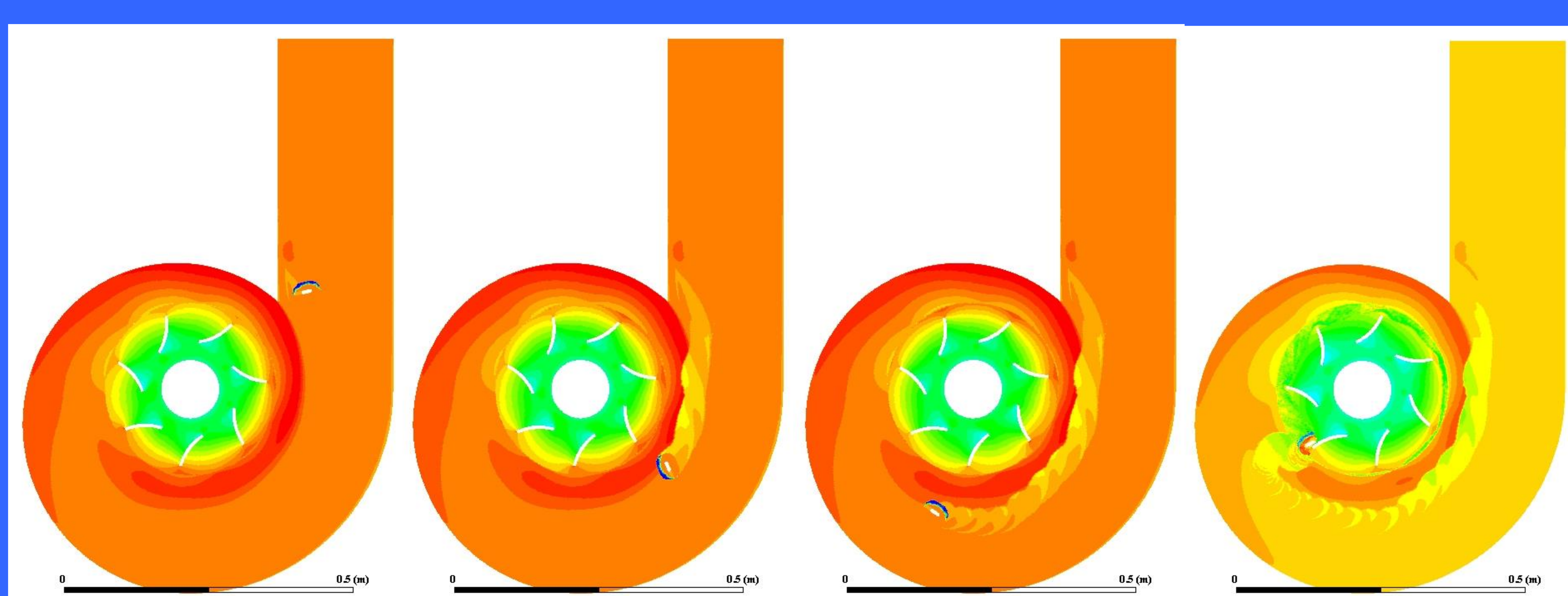
(a) Flow streamlines through points A, B and C
(b) object pathways released from position A



VARIOUS TEST CONDITIONS EXAMINED NUMERICALLY

Cases	Flow rate (% Q_N)	Num. of blades	Object shape (l:c)
C1 (reference)	High 100	7	Thin 4:1
C2	Low 70	7	Thin 4:1
C3	High 100	9	Thin 4:1
C4	High 100	7	Thick 4:2

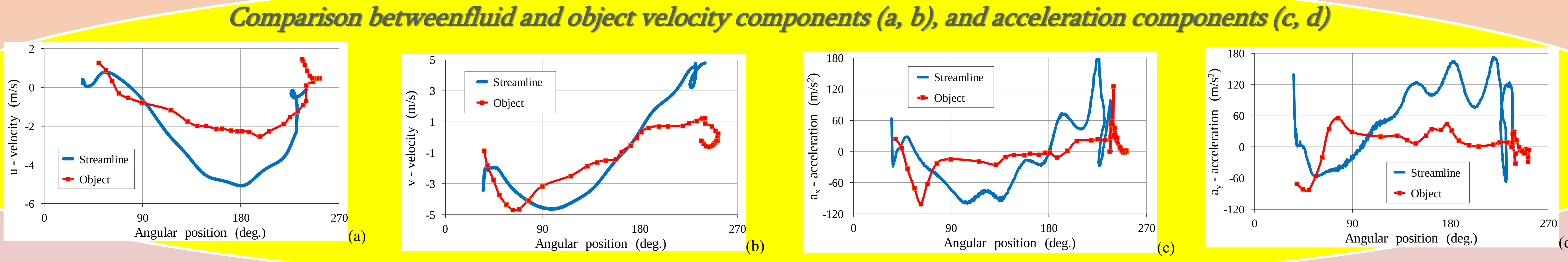
Indicative snapshots from the simulated motion of an object/fish motion through the turbine



Conclusions

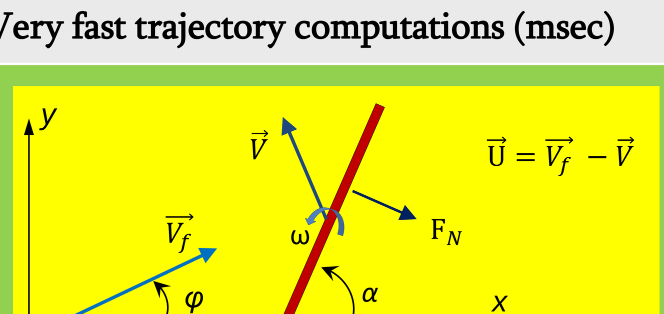
- Difference in object path between some cases are substantial.
- All paths show remarkable deviation from the flow streamlines.
- Object velocity and acceleration also show remarkable differences from the streamlines, especially near the runner.
- Overset technique is quite accurate and can produce realistic results.
- But it is computationally costly – hence not suitable for fish friendliness assessment and design optimization.

Comparison betweenfluid and object velocity components (a, b), and acceleration components (c, d)



B. Hydrodynamic Method (approximate)

- Object motion driven by the normal force /torque acting on a rotating plate.
- Functions of the angle of attach. 3 Degrees-of-Freedom object motion.
- Very fast trajectory computations (msec)

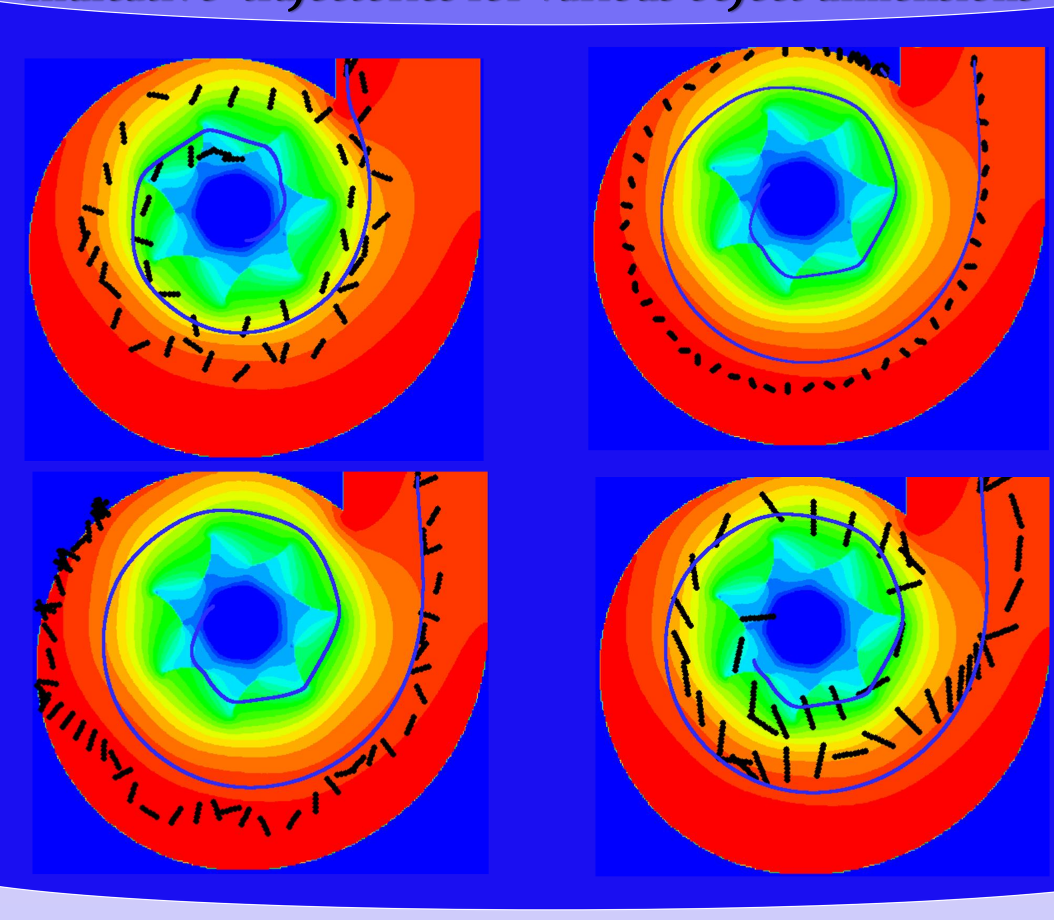


$$m\frac{du}{dt} = C_N(\alpha-\varphi)\frac{\rho}{2}U^2L\sin(\alpha)$$

$$m\frac{dv}{dt} = -C_N(\alpha-\varphi)\frac{\rho}{2}U^2L\cos(\alpha)$$

$$I_{zz}\frac{d\omega}{dt} = -C_M(\alpha-\varphi)\frac{\rho}{2}U^2L^2$$

Indicative trajectories for various object dimensions



Scheduled numerical methodologies

- Calibration of hydrodynamic method to produce results close to the overset simulation.
- Deep Neural Networks for instant reproduction of the flow field around the moving object.
- Implication of a meshless CFD tool (e.g. SPH) for one- or two-way FSI.

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