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Effect of underestimation/overestimation of falling drop parameters on the result of splash simulation in an immiscible liquid system

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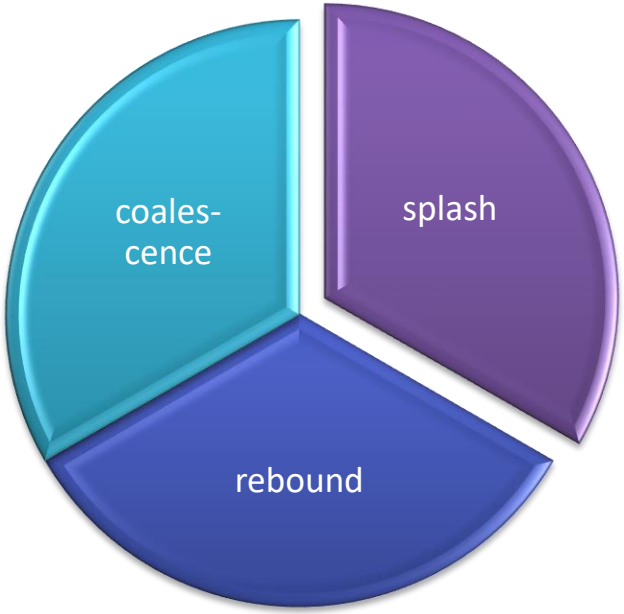
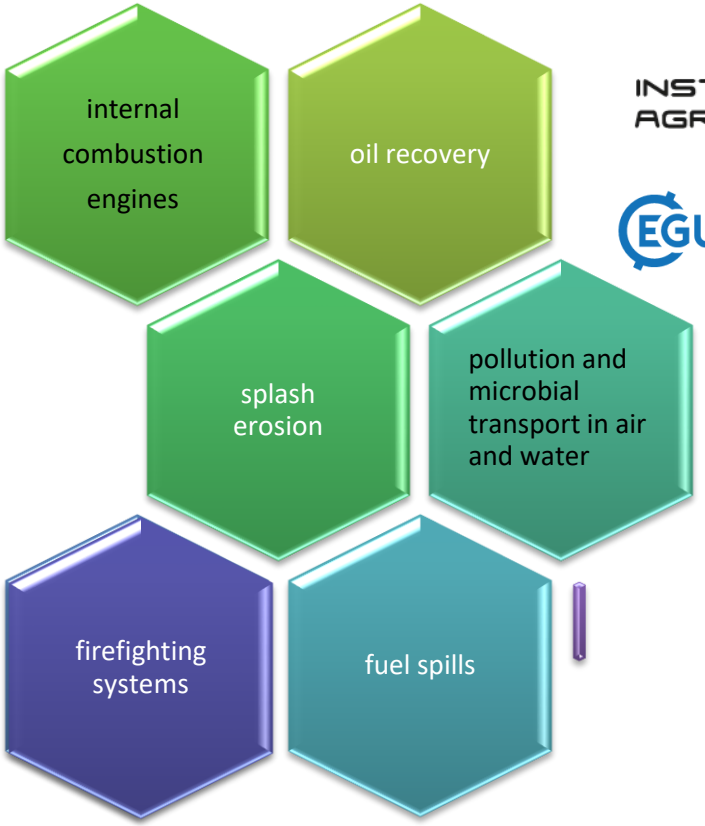
Introduction





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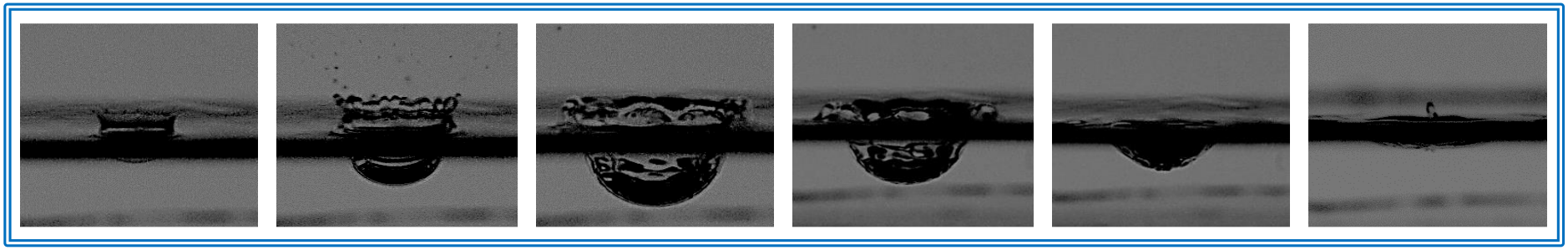

The aim of study

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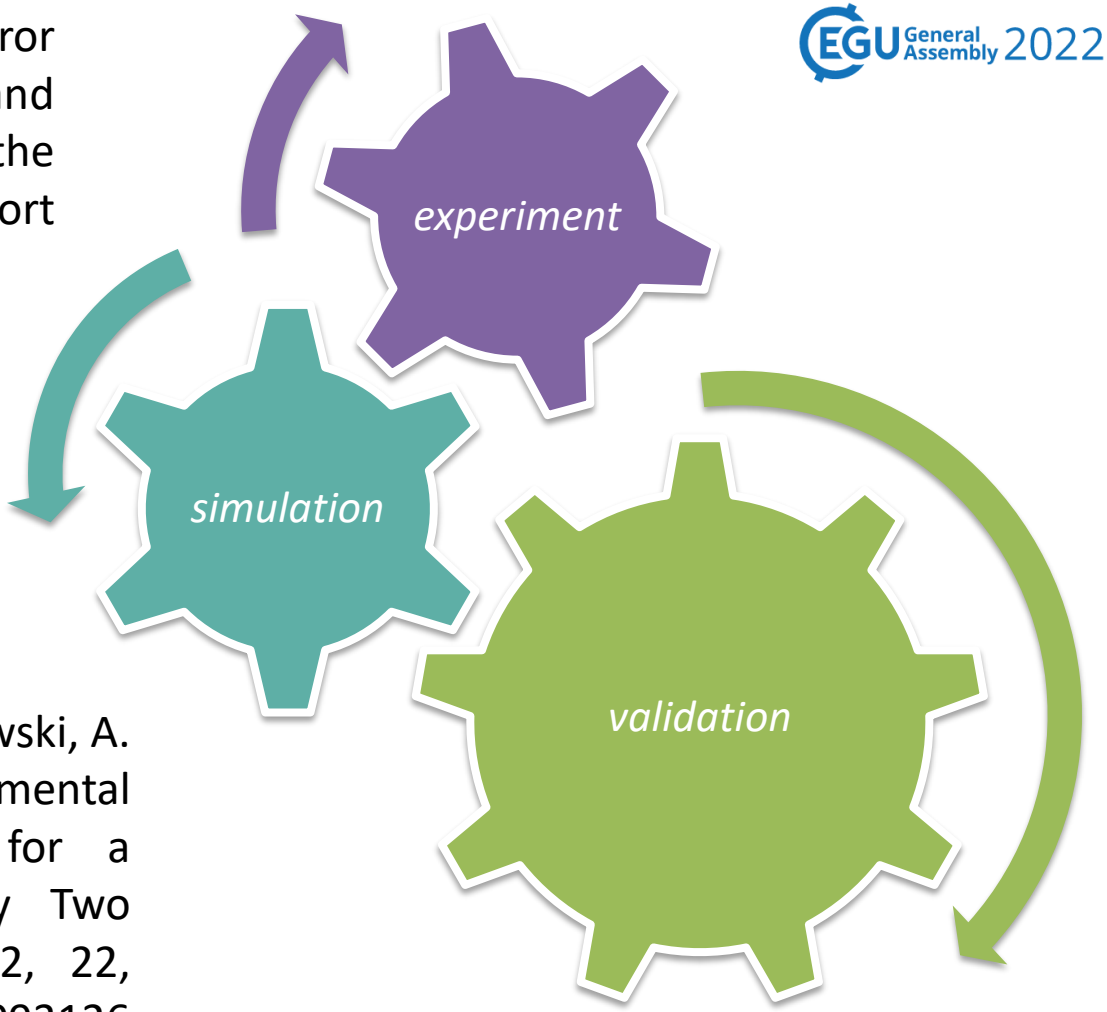
assessment to what extent the error in the reading of drop velocity and size may influence the results of the numerical 3D multiphase transport model



Sochan, A.; Lamorski, K.; Bieganowski, A. Numerical Simulation and Experimental Study of the Drop Impact for a Multiphase System Formed by Two Immiscible Fluids. Sensors 2022, 22, 3126. ttps://doi.org/10.3390/s22093126

Materials and methods

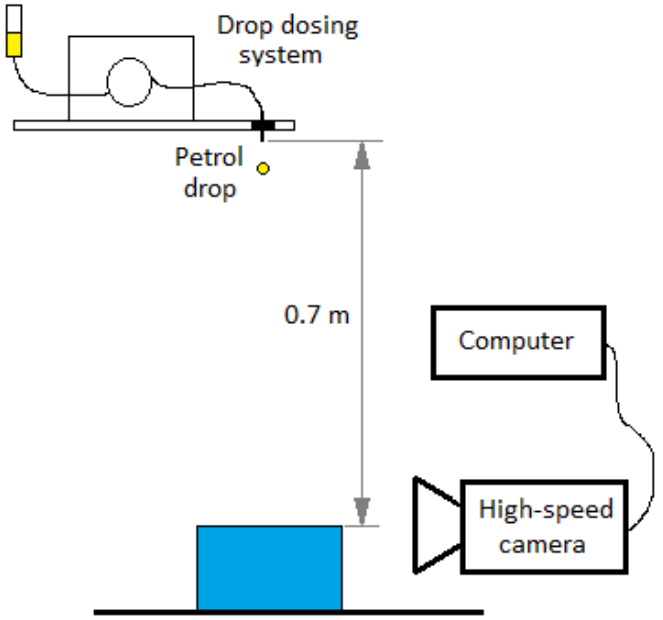
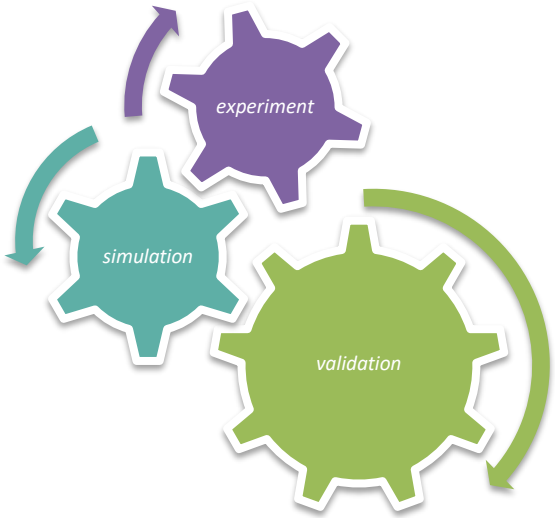


Table 1. Basic characteristics of fluids

Fluid property (in 20 °C)	Water	Petrol	Air
Density ($kg \cdot m^{-3}$)	998.2	748.0	1.2
Kinematic viscosity ($m^2 \cdot s^{-1}$)	1.0 ·10-6	0.4·10-6	14.9·10-6
Surface tension for a fluid-air interface ($mN \cdot m^{-1}$)	72.94	28.42	-
Interfacial tension ($mN \cdot m^{-1}$)	35.0		



- MIRO M310 (Vision Research, USA) high-speed camera with a speed of 2800 fps at resolution 1280 × 800 px;
- Phantom Camera Control software;
- 3 LED back-lighting panels guaranteed luminous flux of 3,500 lumens;
- peristaltic pump Aqua-trend Series 100 Micro;
- height = 0.7 m;
- dimensions of glass vessel 195 × 195 × 100 mm;
- Weber number – the ratio of inertial to surface tension forces, We=986;

- OpenFOAM computational fluid dynamics software implementing the finite volume method (FVM) for space discretization;

- Image analysis: GNU Image Manipulation Program (GIMP) 2.0

-> the height of the crown (h) – measured from the liquid surface to the highest of the crown spikes,
-> the external width of the crown (w) – measured at the height of the crown spikes at their maximum spread,
-> the depth of the cavity (d) – measured from the liquid surface to the deepest point below the surface.

Model validation stage

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Table 2. Symbols and input data for 13 variants of simulation

Modelling variant		Drop properties	
		diameter (d) (mm)	velocity (v) ($m \cdot s^{-1}$)
d(-3)	-3 pixels	3.00	3.37
d(-2)	-2 pixels	3.10	
d(-1)	-1 pixel	3.20	
d,v(0)	Read from the recorded frame	3.30	
d(+1)	+1 pixel	3.40	
d(+2)	+2 pixels	3.50	
d(+3)	+3 pixels	3.60	
v(-3)	-3 pixels	3.30	3.29
v(-2)	-2 pixels		3.32
v(-1)	-1 pixel		3.34
d,v(0)	Read from the recorded frame		3.37
v(+1)	+1 pixel		3.39
v(+2)	+2 pixels		3.42
v(+3)	+3 pixels		3.44

pixel size
100 × 100 µm

Results

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Experiment

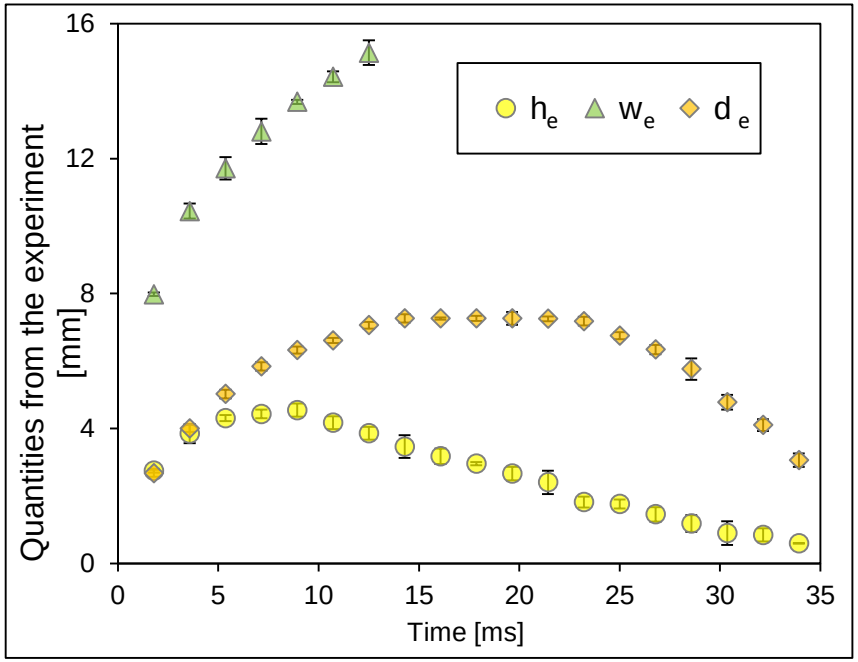
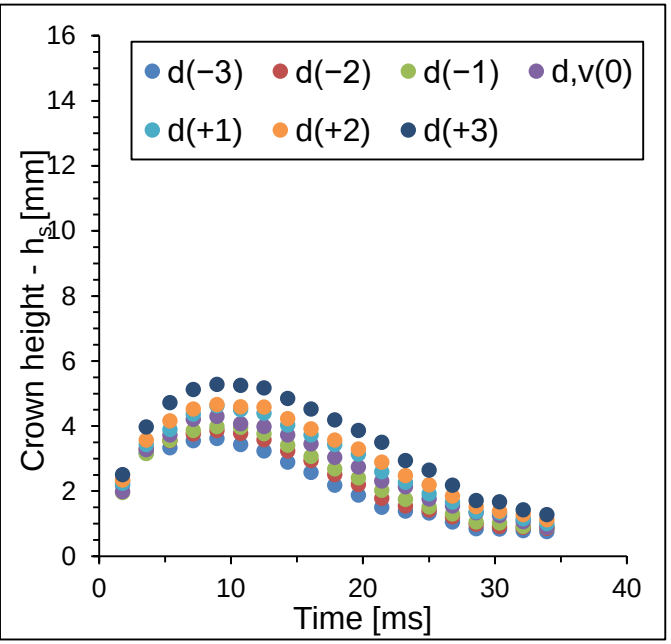
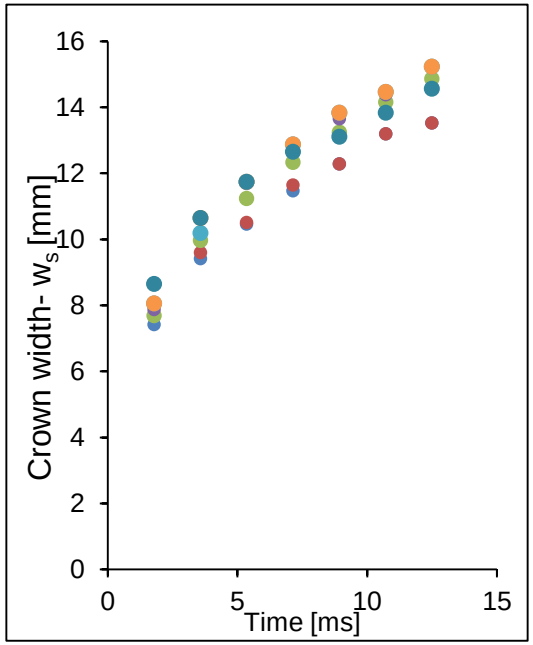


Figure 1. Size of the splash expressed through the parameters of the generated forms: height of the crown (h_e), external width of the crown (w_e), depth of the cavity (d_e), presented in subsequent moments of the real splash phenomenon

Simulations





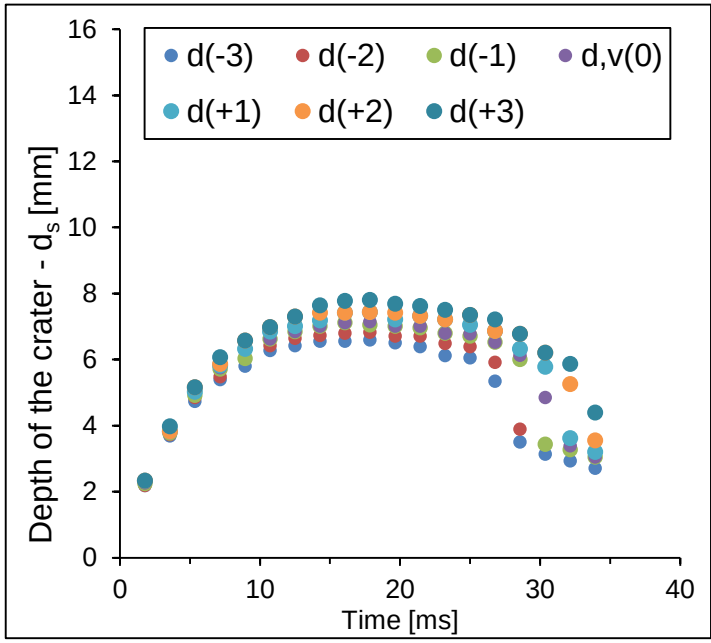


Figure 2. Change in the three splash parameters values: (**a**) height of the crown - h_s, (**b**) external width of the crown - w_s, (**c**) depth of the cavity - d_s, presented in subsequent moments of the splash phenomenon for seven simulations differentiated by the diameter of the falling drop

Table 3. Relative error determined for variants with variable drop diameter

	drop size variants						
	d(-3)	d(-2)	d(-1)	d,v(0)	d(+1)	d(+2)	d(+3)
crown height	0.20	0.15	0.10	-0.03	-0.14	-0.22	-0.43
crown width	0.10	0.09	0.04	0.00	-0.01	-0.01	0.01
cavity depth	0.10	0.06	0.03	0.01	-0.02	-0.03	-0.06

$$Relative\ error = \frac{\text{value from the experiment} - \text{value from the simulation}}{\text{value from the experiment}}$$

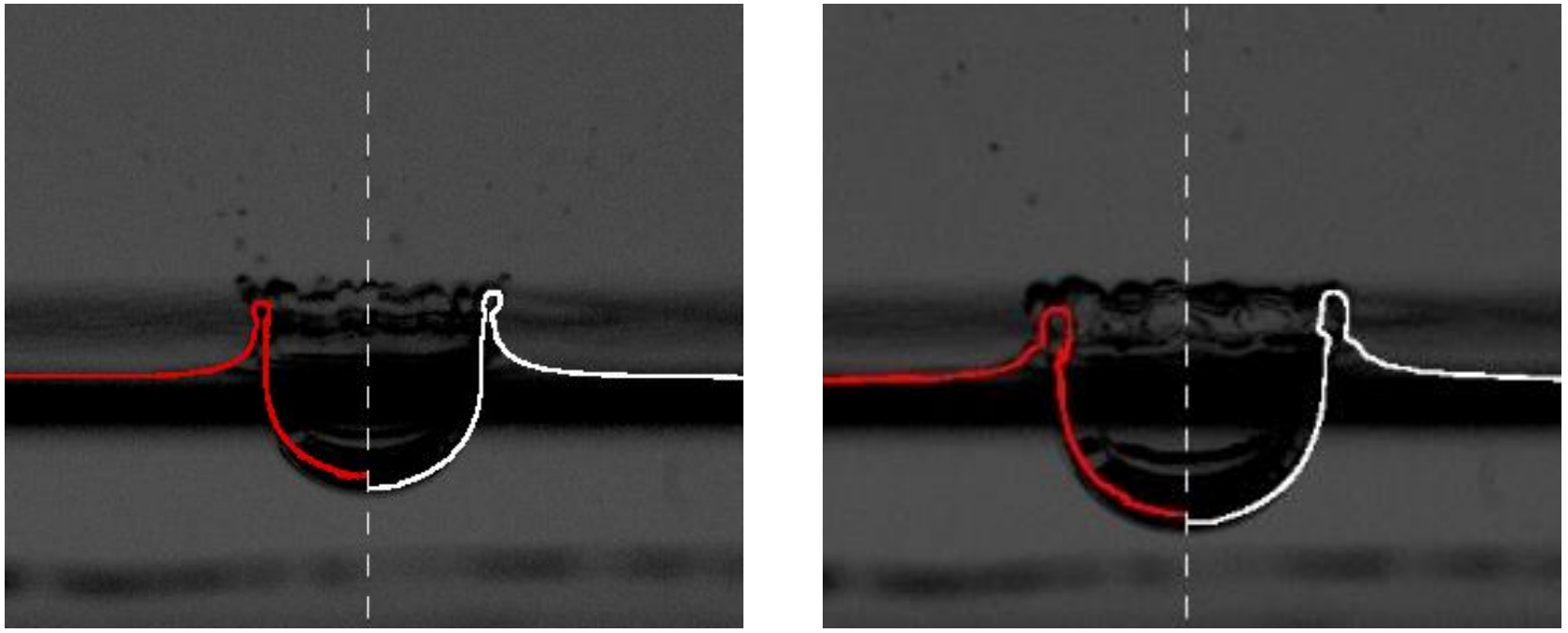


Figure 3. Pictures of the real splash and simulated interfacial profile from variant d,v(0) – white line and the variant d(-3) – red line, at different time intervals: (**a**) 5ms, (**b**), 10 ms.

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