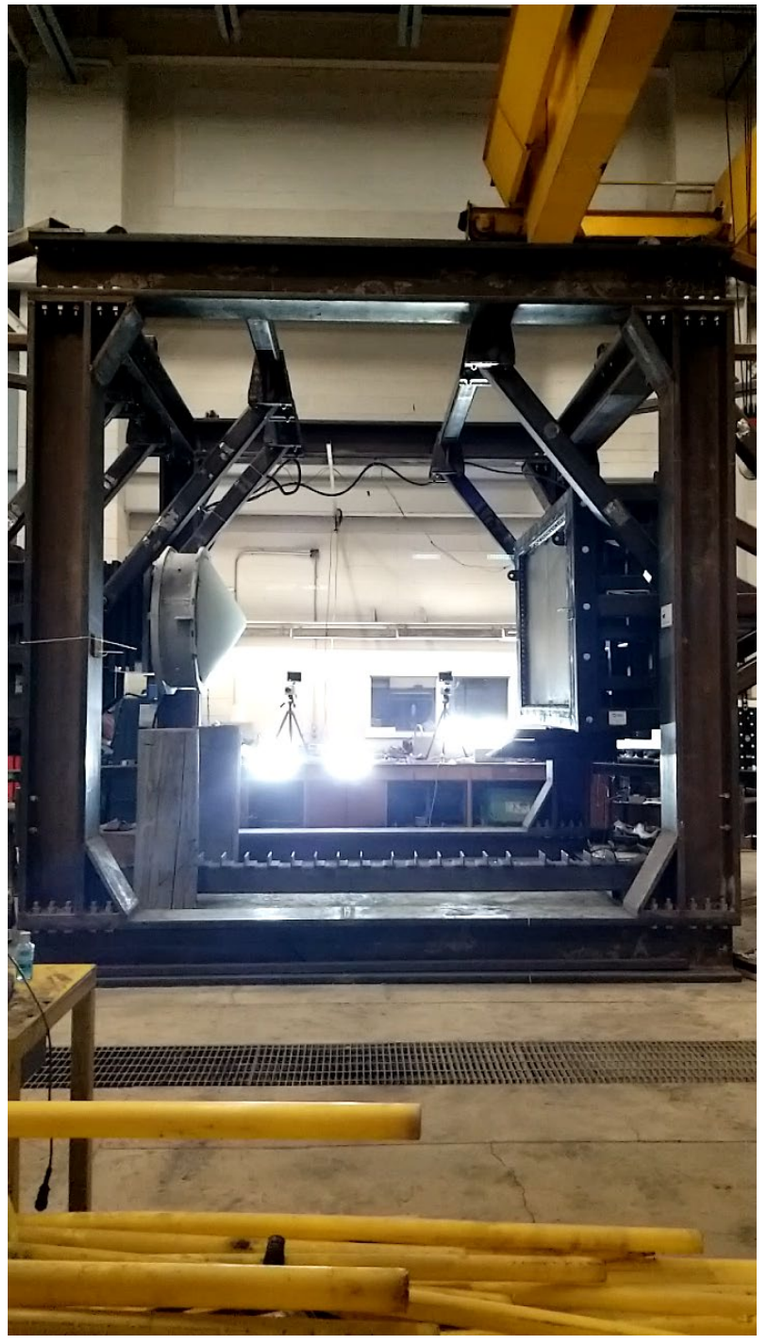
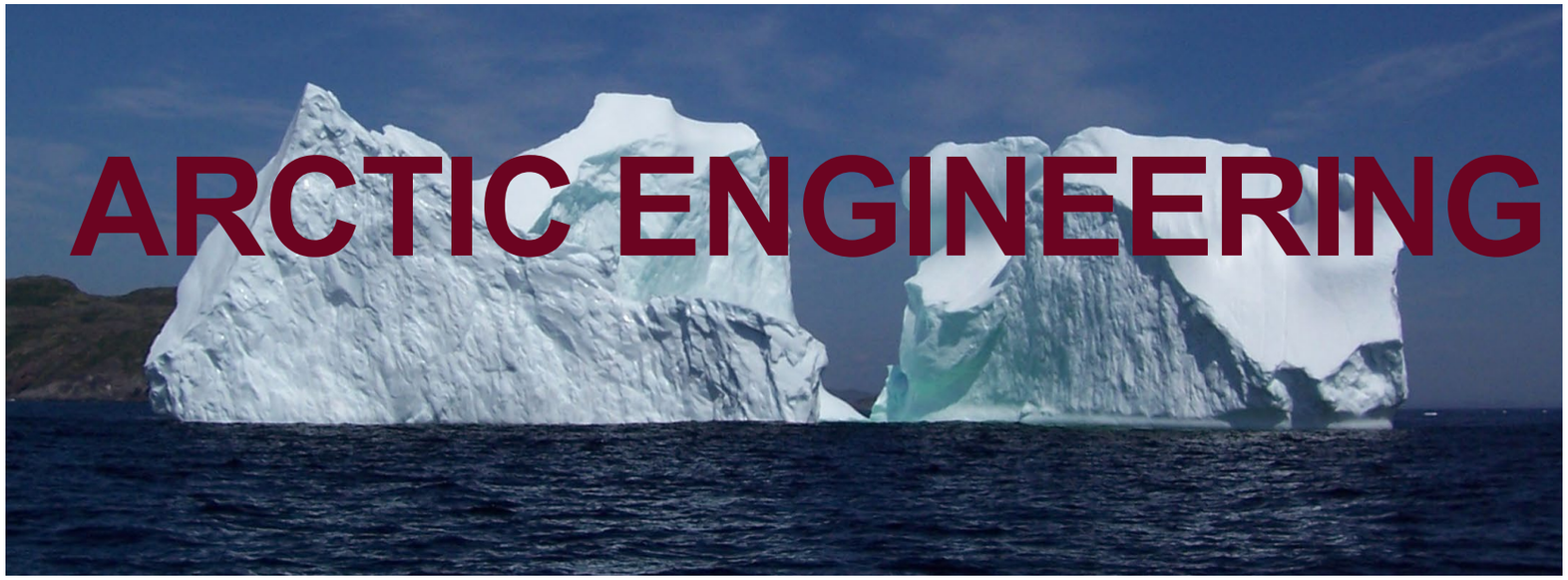
Resilience of Low- and Non-ice-class Vessels in Ice



SNAME SMC
September 2022

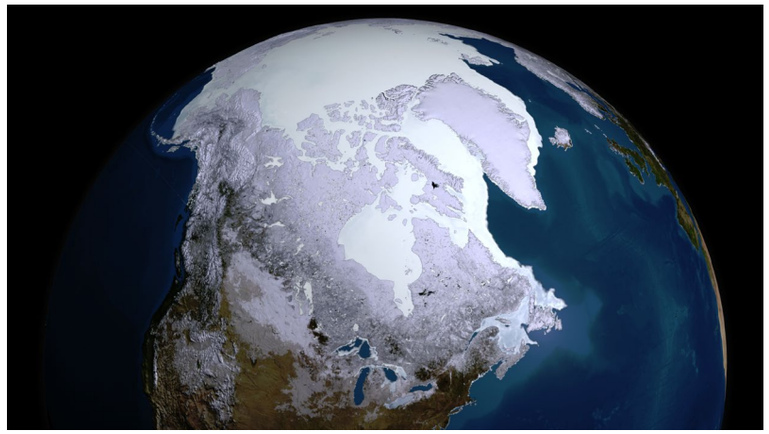
Bruce Quinton, PhD, P.Eng.
Associate Professor, Dept. Head (Acting)
Department of Ocean & Naval Architectural Engineering
Memorial University of Newfoundland



ARCTIC ENGINEERING

Arctic Engineering:

- Ice class ships and offshore structures
- Effects of ice in marine environment
- Effects of polar environment



Why go to the Arctic?

- Trade routes
- Tourism
- Sovereignty and national security
- Science
- Resources

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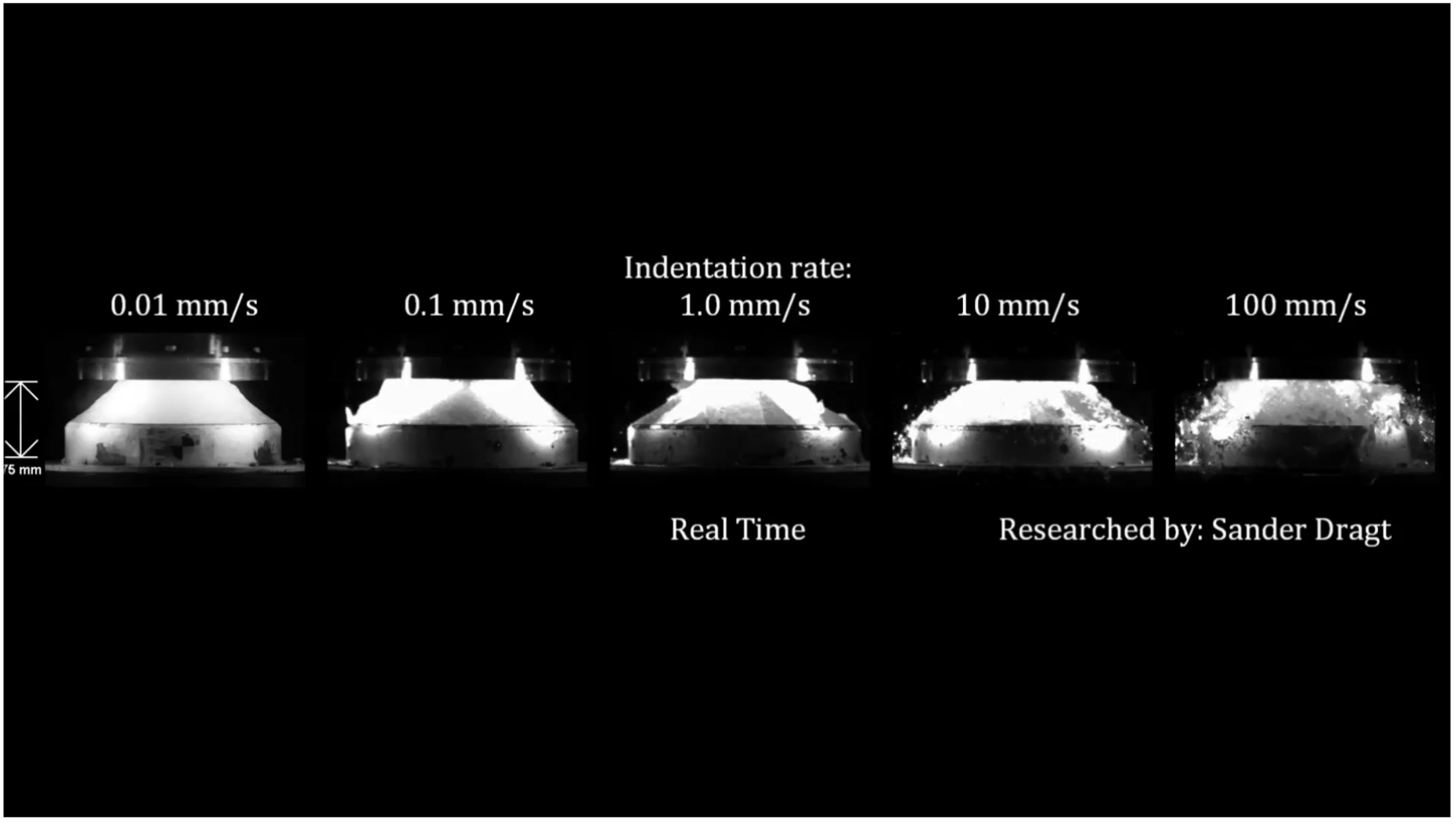
ICE – DIFFICULT TO CHARACTERIZE

USUALLY DEFINES THE DESIGN LOAD



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RESEARCH OVERVIEW

Research Partners:

- **Defence Research & Development Canada (DRDC), VARD Marine Inc., American Bureau of Shipping (ABS)**

Project Duration and Funding: 6 years (2018-2024) – $1M

Selected Project Goals:

- Development and validation of software tools for assessing response of non- and low-ice-class vessel hulls to ice loads
- Advanced material behaviour and fracture characterisation of aged and new steels
- Incorporation of moving load effects in hull assessment tools

Why?

- To support Canadian and NATO activities in the Polar regions
  - Search and rescue
  - Sovereignty and national security
  - Extreme emergency/critical scenarios

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EXPERIMENTS, MODELS, TOOLS

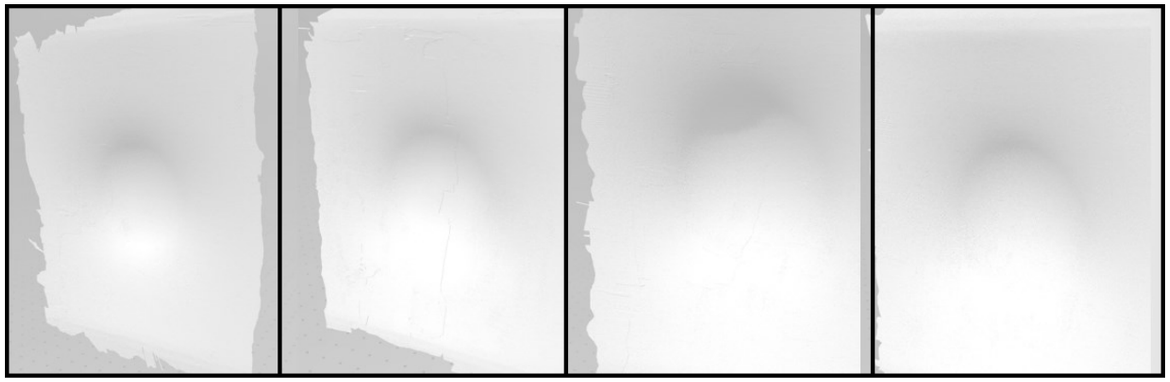
Large Pendulum Apparatus:

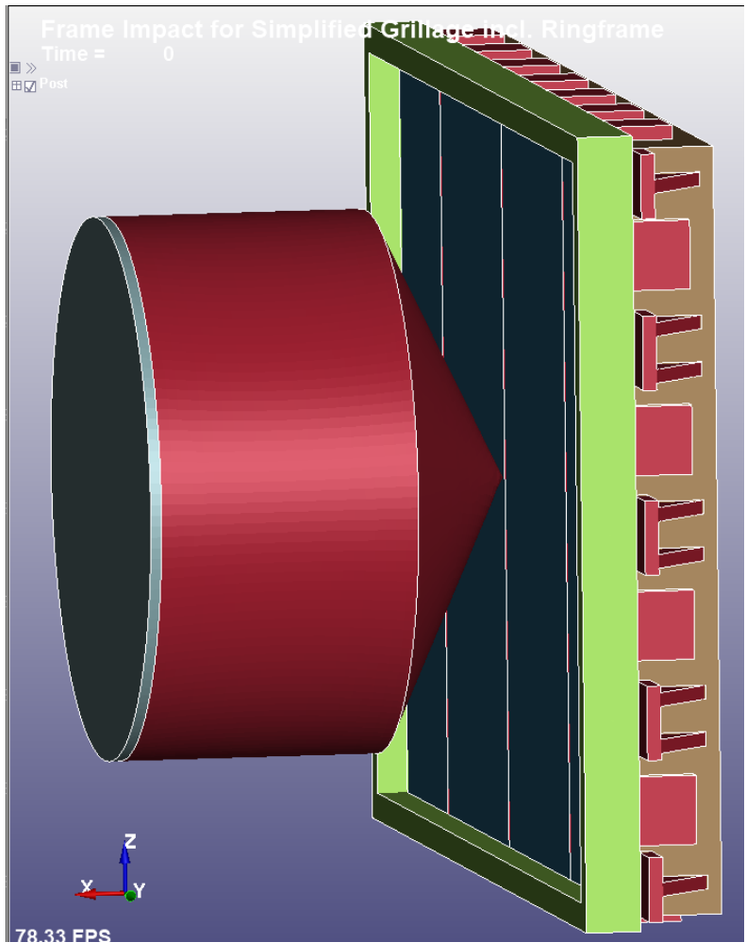
- Left side: ice feature or a rigid indenter
- Right side: full-scale stiffened panel or a plate
- Up to 8.8 m/s closing speed (generating up to ~92 kJ)

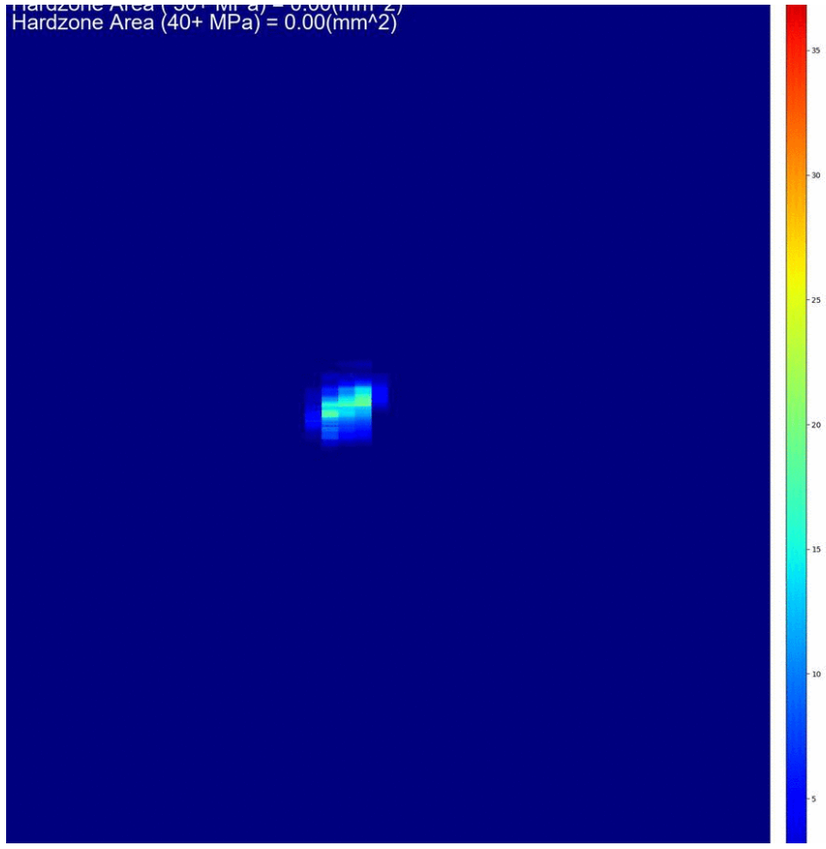
Full-scale Structure

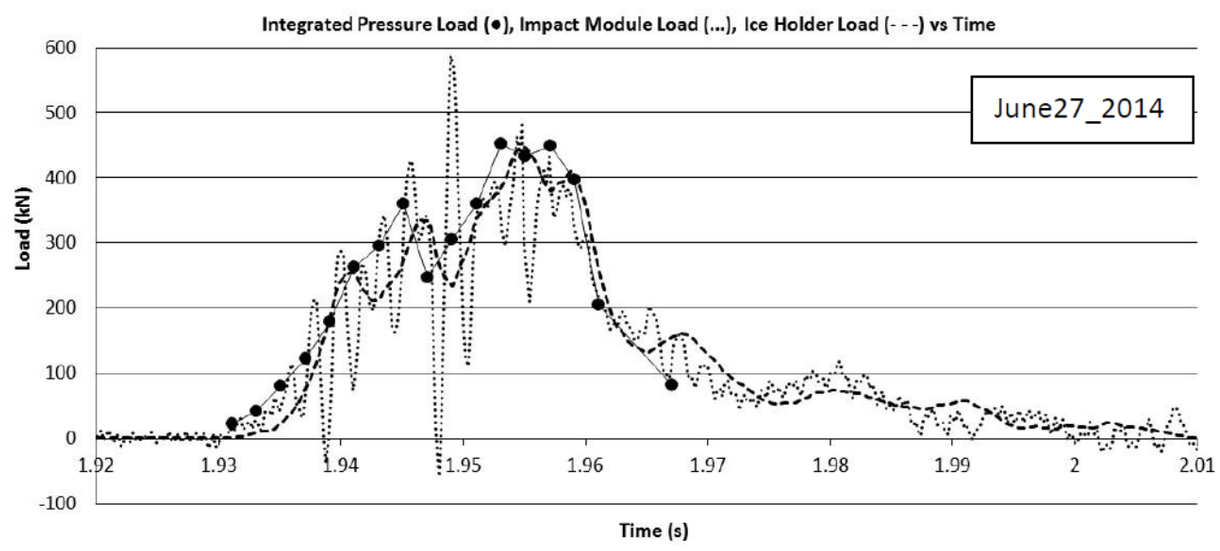
- 80” Wide x 53.5” Tall
- Three 7”x4” x 8.60lbT frames

EXPERIMENTS, MODELS, TOOLS









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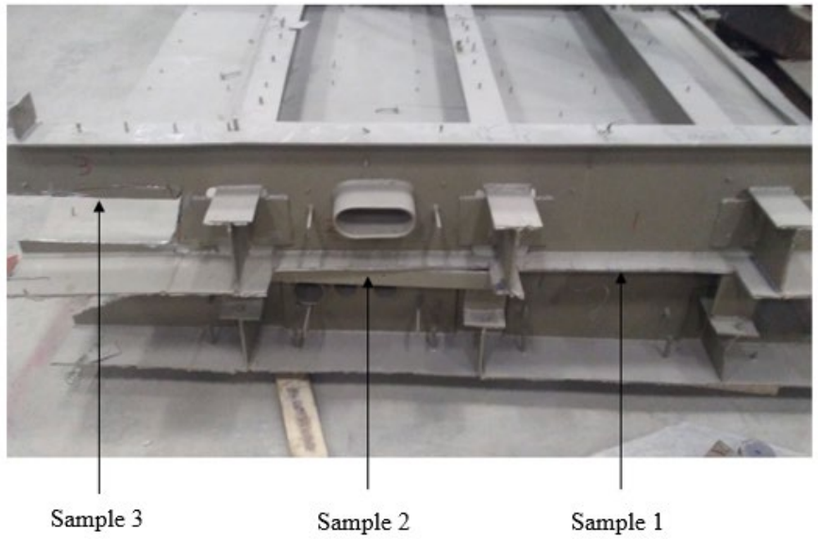
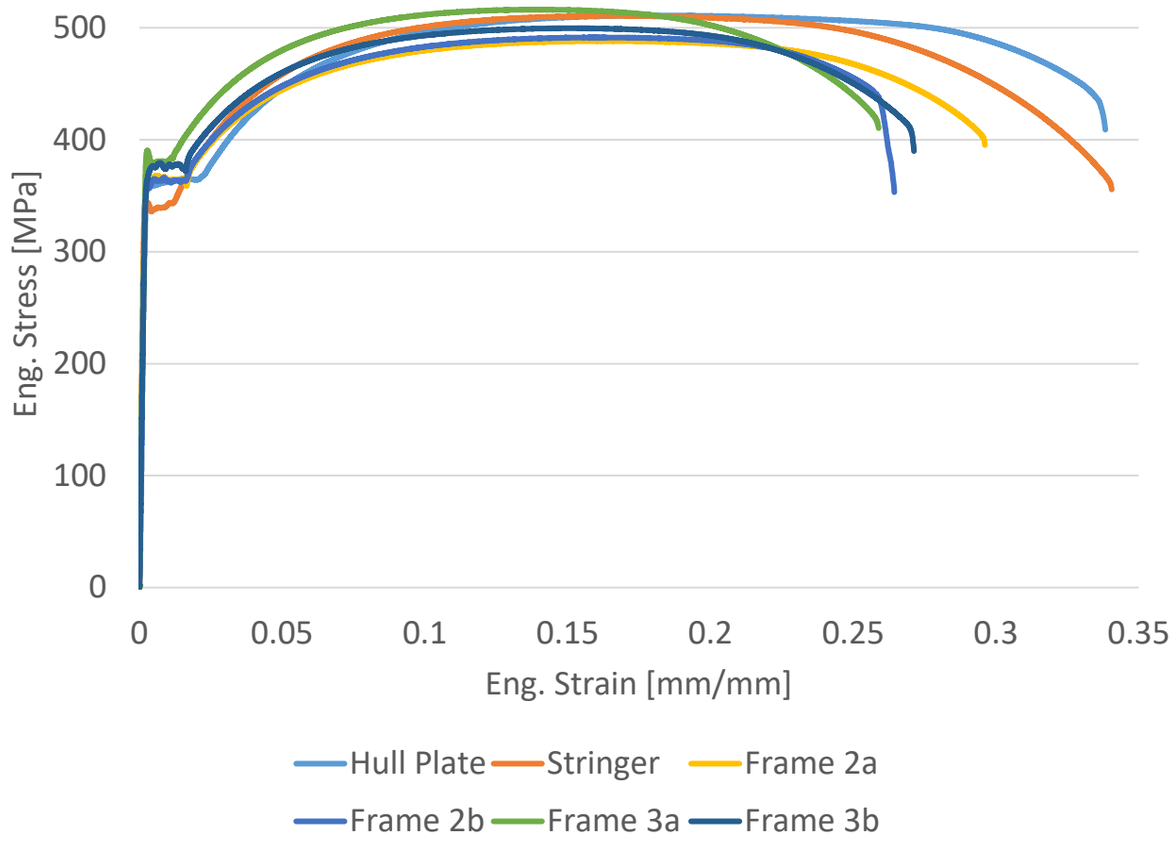
AGED AND NEW MATERIALS CHARACTERIZATION





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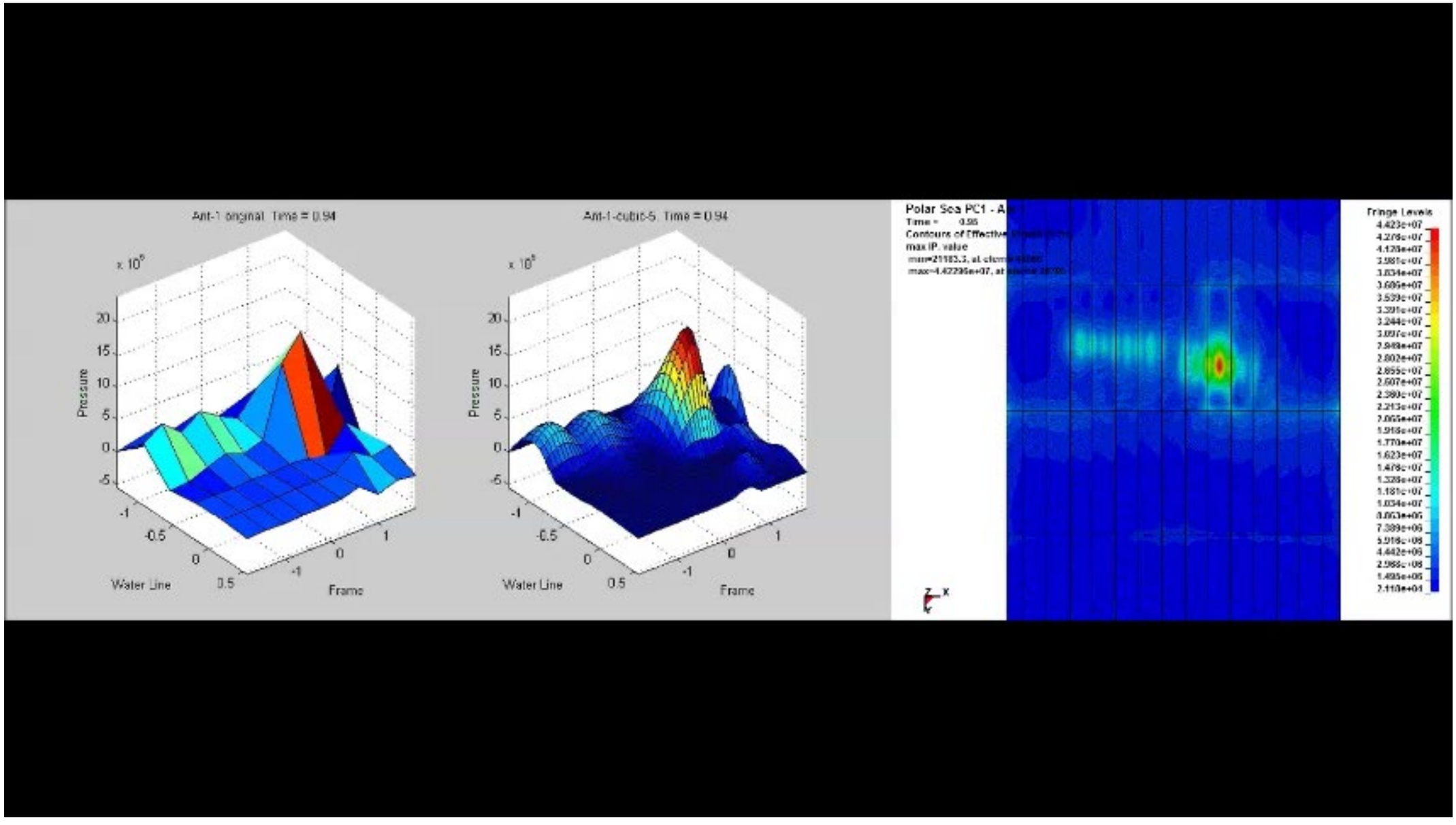
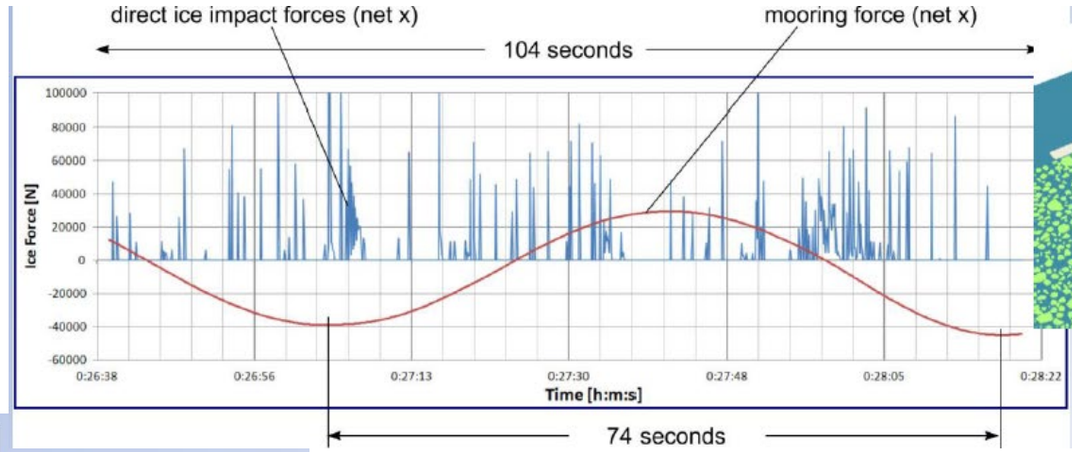
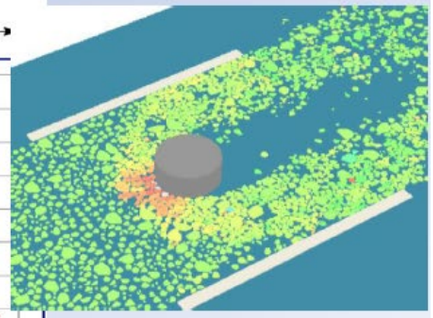
4D (ICE) PRESSURE METHOD (4DPM)



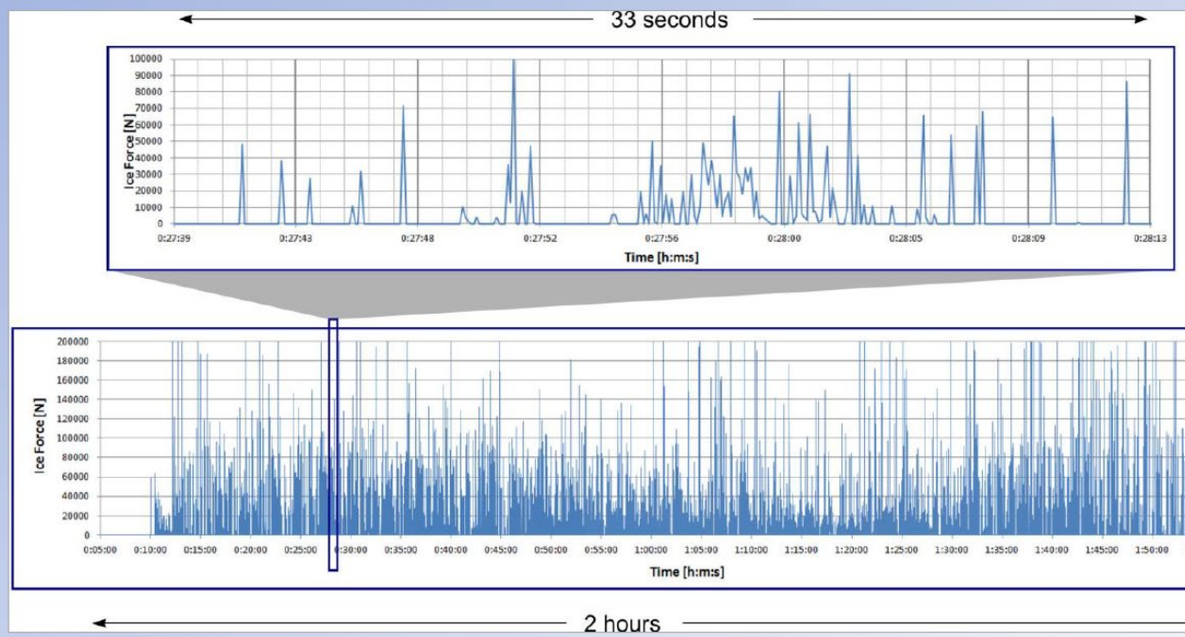
EXPERIMENTS, MODELS,

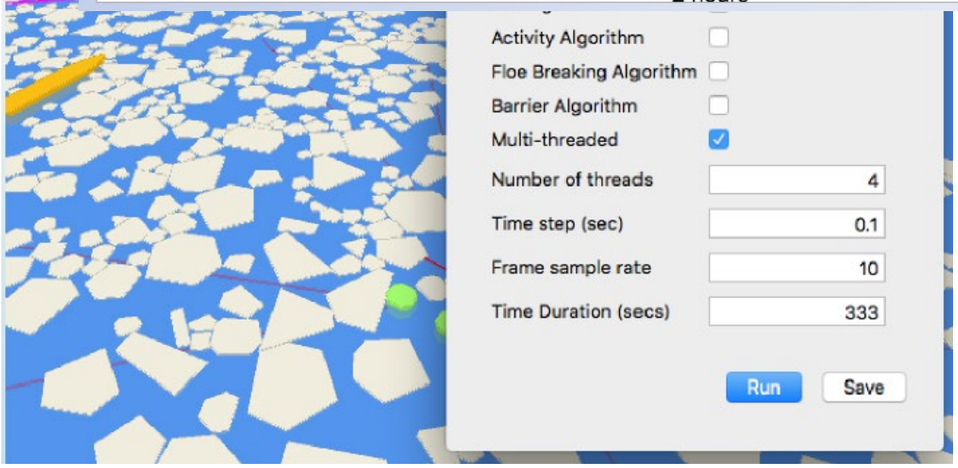
TOOLS – GEM





pack ice force trace net X force from impacts
- very rapid load spikes





Ice impacts on vessel
(one record for every impact)

Time history of vessel
(one record for every timestep)

Item	Description	units
1	time	(h:mm)
2	vessel_position_x	(m)
3	vessel_position_y	(m)
4	vessel_orientation	(deg)
5	vessel_velocity_x	(m/sec)
6	vessel_velocity_y	(m/sec)
7	V_surge	(m/sec)
8	V_sway	(m/sec)
9	vessel_omega	(deg/sec)
10	hydrodynamic_force_x	(N)
11	hydrodynamic_force_y	(N)
12	hydrodynamic_force_N	(Nm)
13	ice_force_x	(N)
14	ice_force_y	(N)
15	ice_force_N	(Nm)
16	mooring_force_x	(N)
17	mooring_force_y	(N)
18	mooring_force_N	(Nm)
19	propeller_force_x	(N)
20	propeller_force_y	(N)
21	propeller_force_N	(Nm)
22	rudder_force_x	(N)
23	rudder_force_y	(N)
24	rudder_force_N	(Nm)
25	engine_power(kW)	(kW)
26	prop#1_thrust	(N)
27	prop#1_torque	(Nm)
28	prop#1_spin_speed	(RPM)
29	prop#1_power	(kW)
30	rudd#1_angle	(deg)

Item	Description	units
1	time	(h:mm)
2	vessel_position_x	(m)
3	vessel_position_y	(m)
4	vessel_orientation	(deg)
5	vessel_velocity_x	(m/sec)
6	vessel_velocity_y	(m/sec)
7	V_surge	(m/sec)
8	V_sway	(m/sec)
9	vessel_omega	(deg/sec)
10	ice_centroid_x	(m)
11	ice_centroid_y	(m)
12	ice_orientation	(deg)
13	ice_velocity_x	(m/sec)
14	ice_velocity_y	(m/sec)
15	ice_omega	(deg/sec)
16	vessel_beta0	(deg)
17	vessel_beta1	(deg)
18	ice_wedge_angle	(deg)
19	hull_wedge_angle	(deg)
20	impact2D_direction_x	-
21	impact2D_direction_y	-
22	impact2D_location_x	(m)
23	impact2D_location_y	(m)
24	norm_vel_ship2D	(m/sec)
25	norm_vel_ice2D	(m/sec)
26	norm_vel2D	(m/sec)
27	tan_vel2D	(m/sec)
28	eff_mass_vessel2D	(kg)
29	eff_mass_ice2D	(kg)
30	eff_mass_comb2D	(kg)
31	impulse2D_x	(N-s)
32	impulse2D_y	(N-s)
33	norm_vel3D	(m/sec)
34	eff_mass_vessel3D	(kg)
35	eff_mass_ice3D	(kg)
36	eff_mass_comb3D	(kg)
37	ice_thickness	(m)
38	ice_Po	(MPa)
39	ice_Sf	(MPa)
40	iceoal	(#)
41	flex_limit	(N)
42	ice_mass	(kg)
43	ice_id	-
44	strucutre_id	-
45	hull_id	-
46	Popov_normal_force3D	(N)
47	fa_3D	-
48	norPen3D	m
49	verPen3D	m
50	contact_type	-

THANK YOU

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