Bell 525 Ditching and Flotation Stability Testing

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EASA Rotorcraft Symposium, December 6-7, 2016

Bell 525 Relentless

- Category A Operations
- Dual Pilot IFR
- Max GW 20,500 Pounds
- 12,000 Feet Density Altitude Maximum
- Inadvertent Icing
- Offshore Ditching Capability for Sea State 6

Certification for Ditching

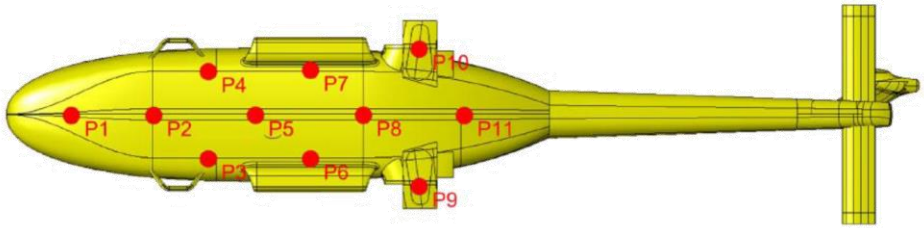
- **14 CFR § 29.563 [Amdt. 29-30, Eff. 4/5/90]**
  - Structural ditching provisions. If certification with ditching provisions is requested, structural strength for ditching must meet the requirements of this section and Sec. 29.801(e).
    - (a) *Forward speed landing conditions.* The rotorcraft must initially contact the most critical wave for reasonably probable water conditions at forward velocities from zero up to 30 knots in likely pitch, roll, and yaw attitudes. The rotorcraft limit vertical descent velocity may not be less than 5 feet per second relative to the mean water surface. Rotor lift may be used to act through the center of gravity throughout the landing impact. This lift may not exceed two-thirds of the design maximum weight. A maximum forward velocity of less than 30 knots may be used in design if it can be demonstrated that the forward velocity selected would not be exceeded in a normal one-engine-out touchdown.
- **14 CFR § 29.801 [Amdt. 29-12, Eff. 2/1/77]**
  - Ditching.
    - (c) The probable behavior of the rotorcraft in a water landing must be investigated by model tests … Scoops, flaps, projections, and any other factors likely to affect the hydrodynamic characteristics of the rotorcraft must be considered.
    - (d) It must be shown that, under reasonably probable water conditions, the flotation time and trim of the rotorcraft will allow the occupants to leave the rotorcraft and enter the liferafts required by Sec. 29.1415. … If the rotorcraft has fuel tanks (with fuel jettisoning provisions) that can reasonably be expected to withstand a ditching without leakage, the jettisonable volume of fuel may be considered as buoyancy volume.

Water Ditching Test Facility

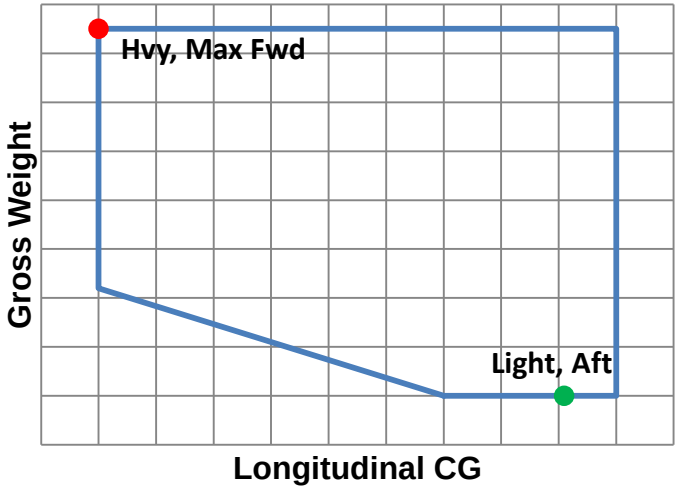
<u>Certification testing June 2016</u>
Laboratoire de Mécanique des Fluides
(LMF – Fluid Mechanics Laboratory)
Hydrodynamic and Ocean Engineering Tank
Nantes, France

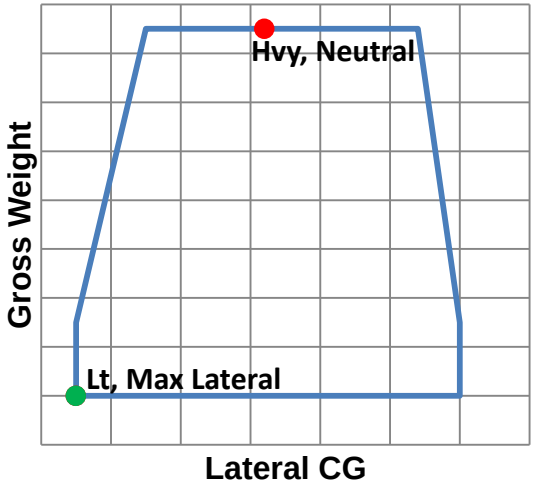
Water Ditching Testing Setup

- **Test article description**
  - 1/12th Froude scaled model to replicate dynamic behavior
  - Wheel gear retracted
  - No floats deployed
  - Max and min GW tested
  - 11 pressure transducers (5 Hz high pass)
  - 3D motion capture (not available for real-time data)



1/12th scale model developed by Sirehna under contract to Zodiac Aerosafety Systems





1/12th Froude Scale Model

- **Froude scale is the ratio of fluid resistance to gravity**

$$Fn = \frac{Inertia\ force}{Gravity\ force} \propto \frac{\rho U^2 L^2}{\rho g L^3} = \frac{U^2}{gL}$$

- **This leads to the following 1/12th scaling**

$$Length_{model} = Length_{real}\left(\frac{1}{12}\right)$$

$$Time_{model} = Time_{real}\sqrt{\frac{1}{12}}$$

$$Velocity_{model} = Velocity_{real}\sqrt{\frac{1}{12}}$$

$$Force_{model} = Force_{real}\left(\frac{1}{12^3}\right)$$

$$Pressure_{model} = Pressure_{real}\left(\frac{1}{12}\right)$$

Tuning for Realistic Ditching Scenario

- **Rotor thrust was tuned to obtain realistic ditching scenarios**
  - **67% rotor lift at max GW**
  - **75% rotor lift at min GW (48% of max GW)**
- **Vertical drop height adjusted to tune contact velocity to 5 ft/s**

$$u = \iint \ddot{u}\ d^2t$$

$$u = u_o + u_o + \frac{1}{2}\ddot{u}t^2$$

$$G_{eff} = \frac{2h}{t^2}$$

$u_0 = \dot{u}_0 = 0 \qquad \ddot{u} \rightarrow G_{eff} \qquad u \rightarrow h$

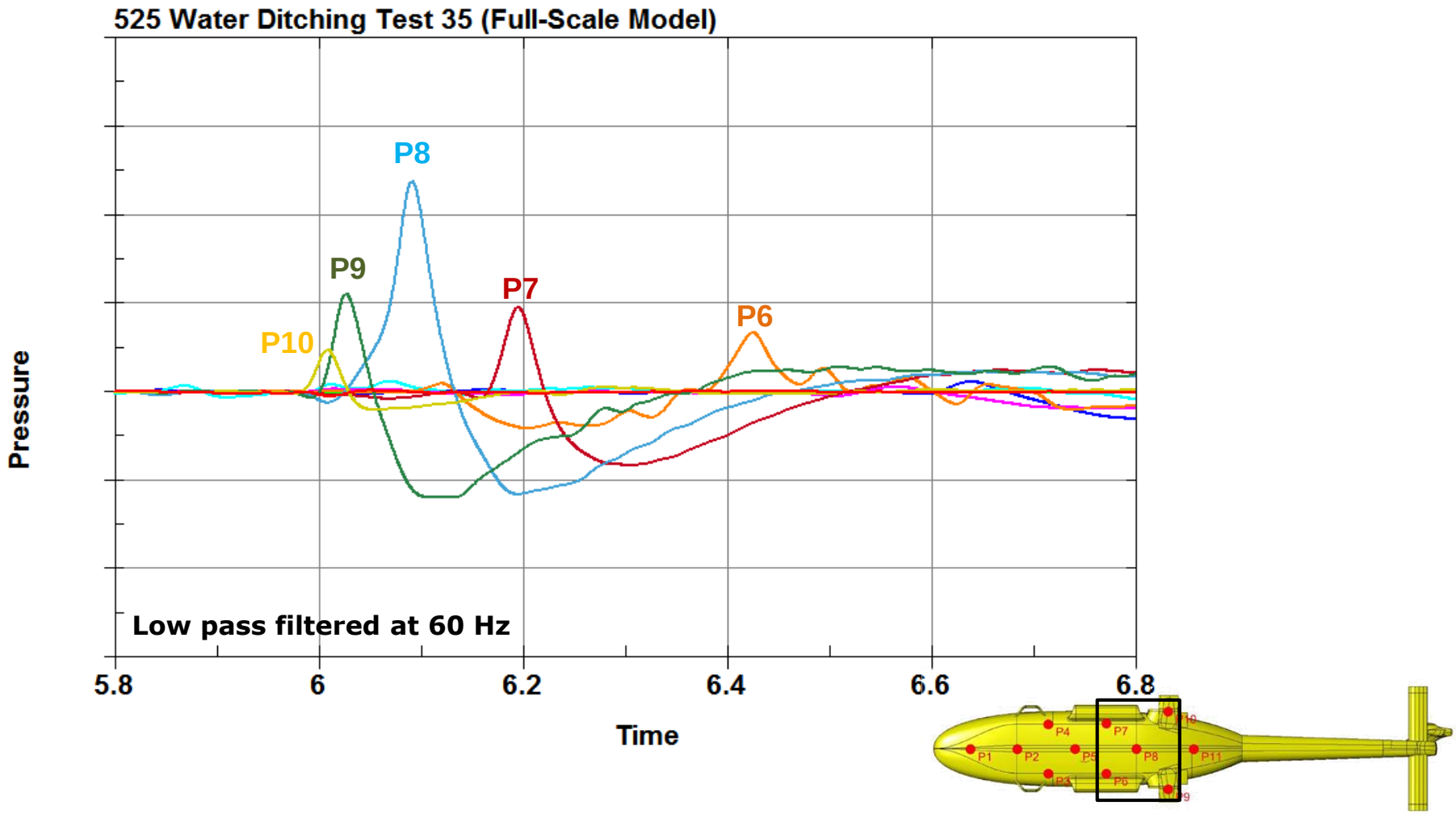
Measure drop height, *h*, and time, *t*, from release to contact

Equating kinetic and potential energies provided test guidance

$$v = \sqrt{2(G_{eff})h}$$

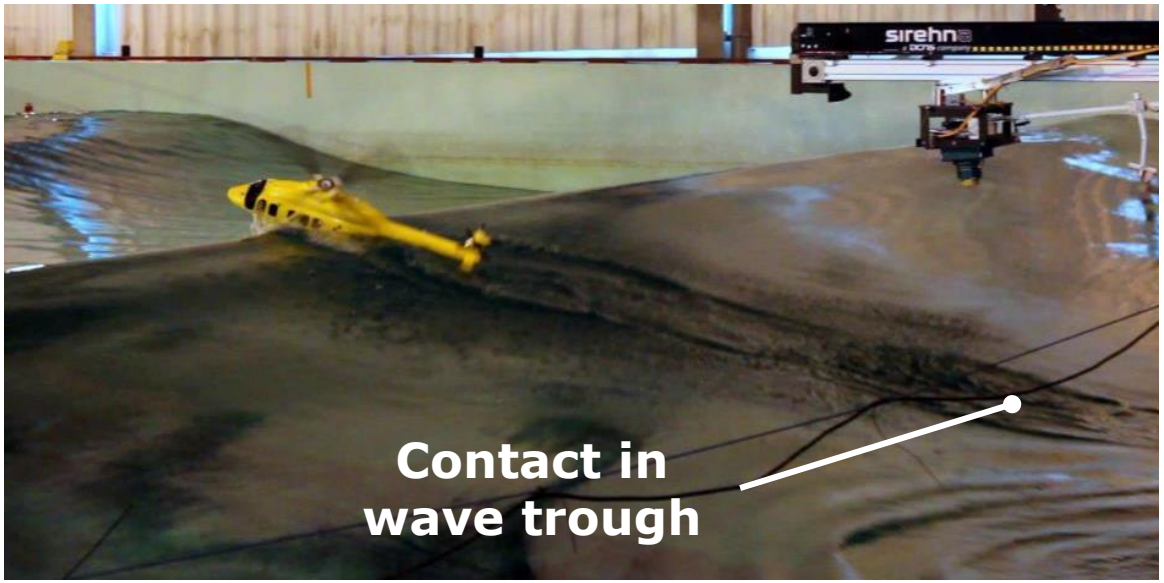
Actual vertical velocity from 3D motion measurement system

Pressure for Ditching at Sea State 0



Water Ditching Testing – § 29.801(c)

- **Ditching water entry in Sea States 0, 4 and 6**
  - **Contact position on wave strongly influences pressure**
    - **Ditching on top of backside of wave is optimum**
  - **In general, pitch, roll, yaw attitude only changed location of pressure distribution**



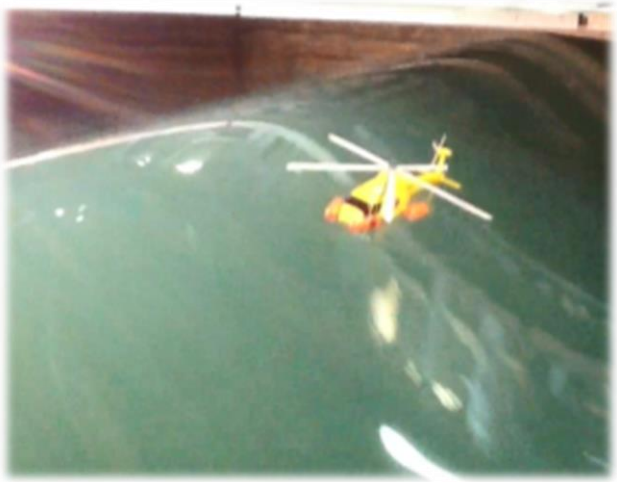
Sea State 6 Water Entry at Max GW

Run 52

- **20,500 lb**
- **Max Fwd CG**
- **Sea State 6**
- **0° Pitch**
- **0° Roll**
- **0° Yaw**

Flotation Stability Testing – § 29.801(d)

- **Test facilities**
  - Development testing June 2013
    - DGA Techniques, Hydrodynamics, Val de Reuil, France
  - Certification testing September 2015
    - NRC Institute for Marine Dynamics, St. John's, Newfoundland, Canada



- **Conditions evaluated**
  - 5 GW-CG configurations
  - Doors open & closed
  - Sea State 2 with degraded floats
  - Sea State 3 with degraded floats
  - Sea State 4 with intact floats
  - Sea State 6 with intact floats
  - Sea State 5 Irregular waves with intact & degraded floats

Conditions Compounded for Conservatism

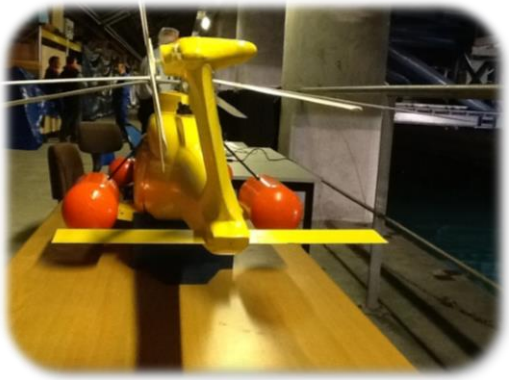
All CGs are left of neutral

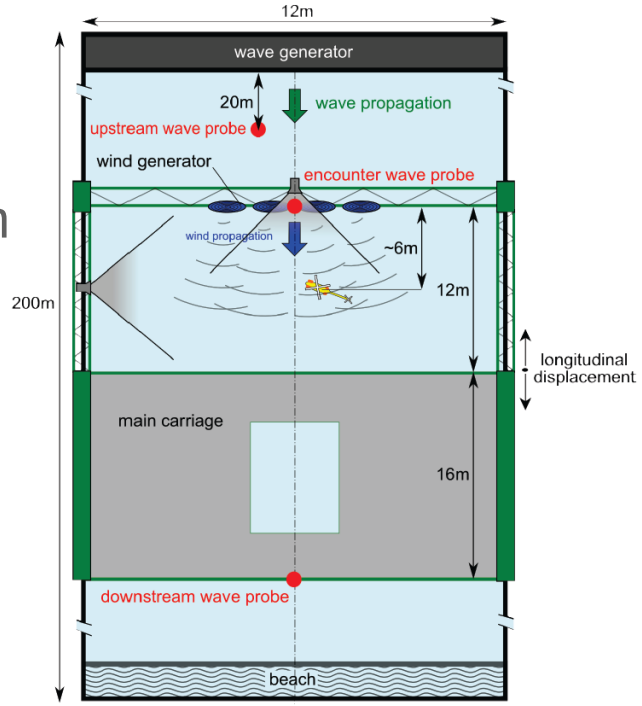
All degraded floats are on left side

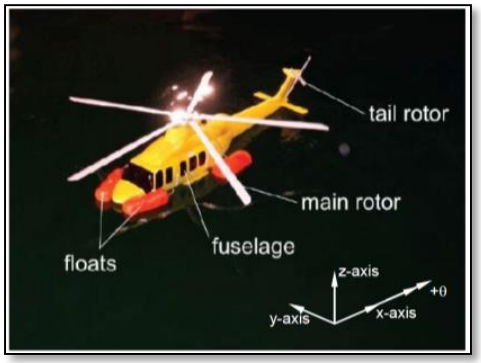
All cases wind impinges on right side

Flotation Stability Test Setup

- **Test article description and setup**
  - 1/10th Froude scaled model
  - Onboard motion data acquisition system

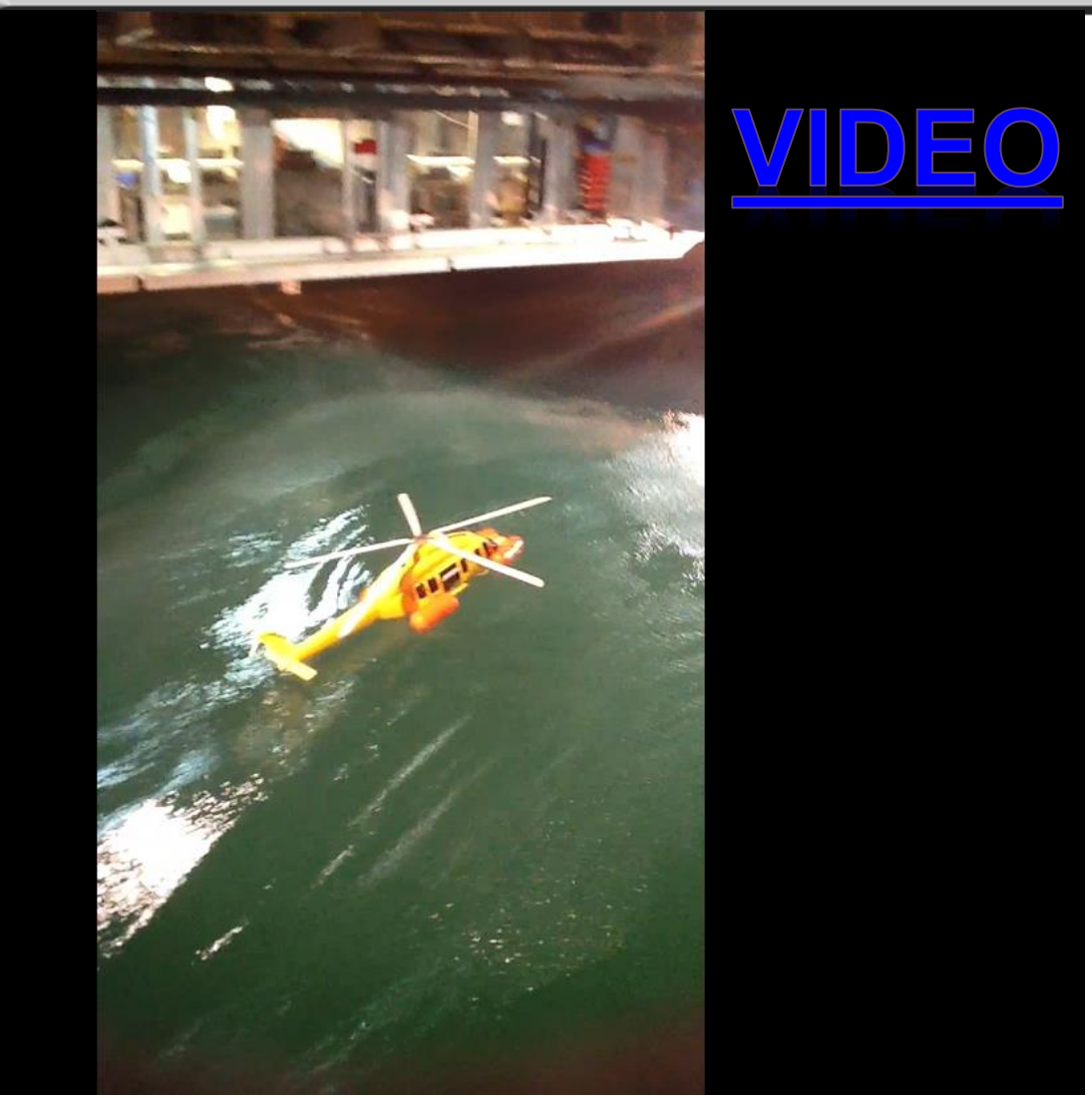






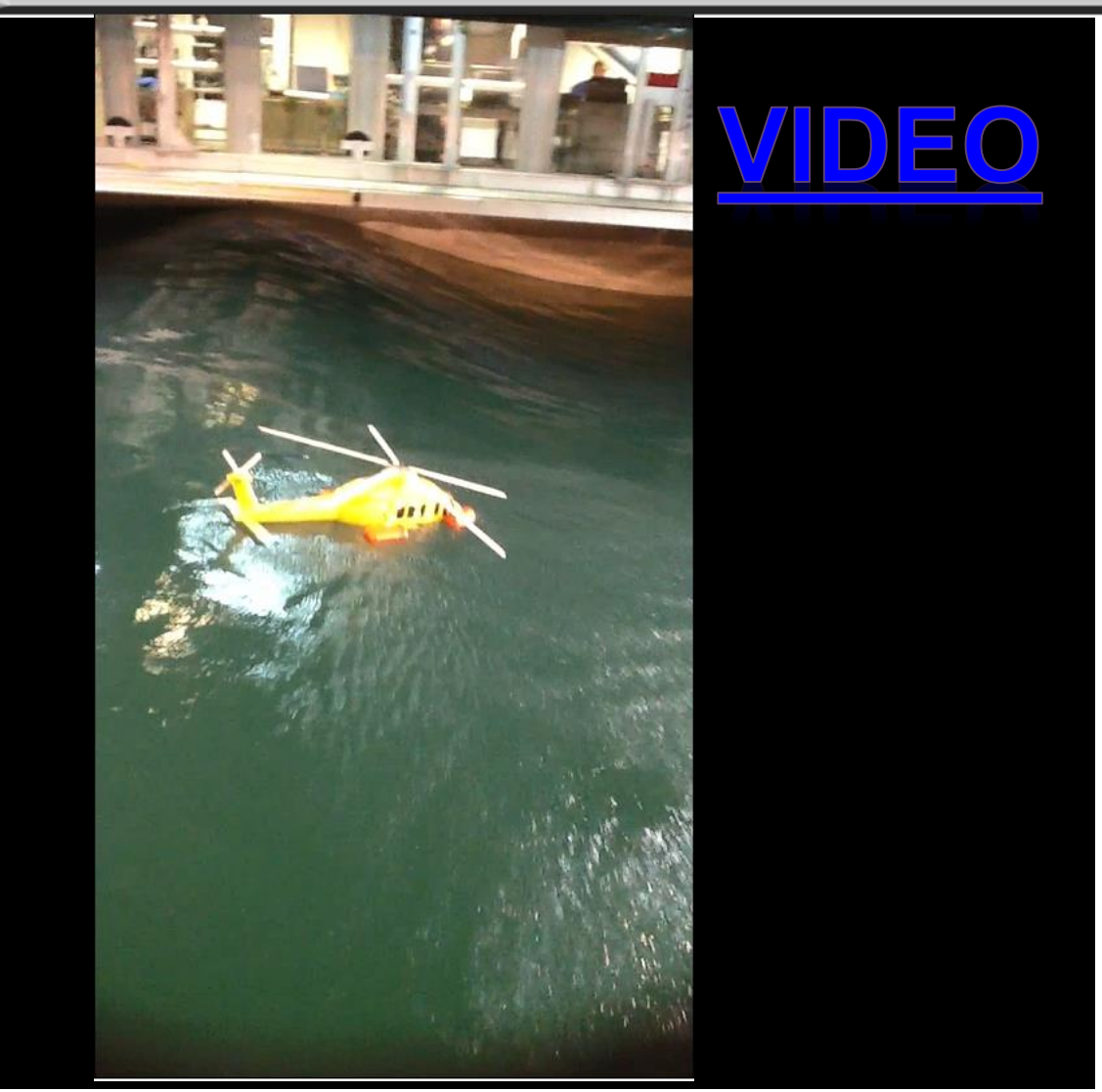
1/10th scale model developed by Sirehna under contract to Zodiac Aerosafety Systems

Sea State 6, 13,000 lb GW at Max Lat CG



- **Flotation observations**
  - Aircraft weather vanes into waves almost immediately after wind is turned on.
  - Doors off resulted in only slight decrease in weather vane tendency.
  - Aft floats mounted on the sponsons enhance stability as outriggers.
  - Equilibrium position the model reached during the first 4-5 waves is maintained for the remainder of the test.

Sea State 6, 20,000 lb GW at Max Aft CG



- **Flotation observations**
  - Despite doors closed, slightly less tendency to weather vane into wind and waves at heavy GW since aircraft floats lower in the water.
  - Equilibrium position the model reached during the first 4-5 waves is maintained for the remainder of the test.
  - Flotation time for this test was 41 sec, which is equivalent to 130 sec full-scale – sufficient time to stop rotor in emergency with brake (35 sec) and egress to rafts (90 sec).

Conclusions

- **The 525 demonstrated stable ditching water entry for all conditions tested in Sea States 0, 4 and 6**
  - **Contact position onto oncoming wave strongly influences pressure distribution**
  - **Optimum contact position is just past top of wave towards backside**
  - **In general, pitch, roll, yaw attitude only influences location of pressure distribution**
- **The 525 demonstrated good flotation stability for all conditions tested in Sea States 2, 3, 4, 6 and irregular waves**
  - **Weight, CG, doors on or off shows little effect on behavior**
  - **With a single float degraded on the left side with starboard wind, the 525 demonstrated good flotation stability**
  - **Flotation test time and trim of the 525 allows occupants time to egress and enter liferafts**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