Exploratory Group EG23

GoR Helicopters

Monitoring responsible: F. Toulmay / EUROCOPTER

Leader: ONERA

Technical proposal
For the establishment of a Garteur Action Group on
"Improvement of SPH methods
for application to helicopter ditching"

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Partners:	CIRA	Italy
	Cranfield University	United Kingdom
	DLR	Germany
	ESI	France
	Eurocopter	France
	Imperial College	United Kingdom
	Laboratory of Mechanics of Lille	France
	Mecalog / Eurosim	France
	ONERA	France
	Politecnico di Milano	Italy

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Summary

Based on the works of the Exploratory Group EG23, the present document describes a technical proposal for the establishment of a new GARTEUR Action Group on the "Improvement of SPH methods for application to helicopter ditching". This research programme follows the Brite Euram project CAST (5^{th} Framework) completed in November 2003 and that aimed at developing a set of simulation tools and a design methodology, which would permit cost effective design and entry-into-service of crashworthy (including impact on water) helicopters.

The objective of the Action Group will be to further investigate SPH method to handle with fluid/structure interaction modelling and will especially address 2 topics: the generation of an experimental database on water impact tests and benchmark activities to evaluate and improve SPH method available among partners.

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Keywords

Fluid/Structure interaction, Smooth Particles, Crash, Helicopter

1 State-of-the-art of fluid/structure interaction modelling, Project motivations

Though crash on water represents around 10% of crash occurrences for helicopters (hard landing: 60%, crash on soft soil – earth, grass, gravel: 30%), most efforts were brought until a recent past to the study of impact of hard soil, notably through European funded research programmes (IMT Crashworthiness for commercial aircrafts, CRASURV, HICAS), partly or fully dedicated to the improvement of numerical analysis tools to handle with such an issue.

This lack of concern for crash on water was also due to the deficiency of reliable analytical tools to handle with fluid/structure interaction. Contrary to impacts on hard soil, which only involve a single field of Mechanics, impacts on soft soil and most of all on water indeed involve 2 fundamentally different Mechanics (Solid and Fluid) that therefore require specific modelling methodologies. The improvement of computer capacities and the recent integration into solid codes of fluid models – appropriate equation of state and material law, new formulations (Arbitrary Lagrangian Eulerian -ALE-, Smooth Particles Hydrodynamics -SPH) - capable of modelling within a single computation fluid and solid domains, potentially permitted to enlarge the scope of crash scenario to the study of ditching.

Though no specific regulation regarding crashworthiness of helicopters on water was imposed yet by certification authorities or even required by aircraft manufacturers, the pressure of the user community and the concern of whether such certification rules may in the mean term come from overseas finally led industrials, research institutes and universities to initiate research programmes aiming at investigating and evaluating the capacities of these new tools to handle with the ditching of aircraft structures. Especially, aeronautical partners pooled their efforts within European projects, in the field of civilian or military aircraft (Brite Euram CRAHVI, CAST), or marine transportation (Brite Euram SEAWORTH).

The CAST project (Crashworthiness of Helicopter on Water: Design of Structures using Advanced Simulation Tools – April 2000/November 2003) especially aimed at developing and improving simulation tools capable of simulating the ditching of helicopter and at defining guidelines for the cost effective design and entry-into-service of crashworthy helicopters with respect to impact on water.

Within this programme, existing methodologies for modelling fluid/structure interaction were investigated, among which the SPH meshless method in which fluid volumes are modelled with particles linked by EOS (Equation Of State) and distribution laws. As no F.E. meshing is generated, the SPH methodology opens wide possibilities for the modelling of complex fluid/structure problems (fluid penetration into a structure, fuel leakage in fuel tanks, impact of highly deformable bodies).

The CAST project permitted to achieve important progresses in the modelling of helicopter ditching and the definition of guidelines for the design of crashworthy helicopters. However, certain limitations were highlighted, notably in the capacity of analysis tools to predict pressure levels at the surface of the impacted structure (also questioning the accuracy of experimental results) and their efficiency in terms of CPU costs, especially for the SPH method. Moreover, most numerical works did not concern severe ditching conditions, as impact tests of full-scale structures did not lead to fluid ingress into the structure.

In the follow-up of the CAST project, the proposed Action Group, whose partnership is mainly based on the CAST consortium, aims at more deeply investigating the SPH method and increasing the level of confidence and efficiency of such tool to predict the crash of helicopter on water.

2 Technical proposal description

2.1 General organisation and objectives

The primary objective of the proposed Action Group is to investigate and evaluate the SPH method by simulating impact tests on water and comparing numerical and experimental results, and to propose developments to increase its capacities to more accurately model fluid/structure interaction, while reducing computation costs. Proposed works therefore targets at:

- Making a review of existing methods to deal with fluid/structure interaction problems, showing advantages and limitations of each method,
- Generating and circulating experimental database on laboratory and simple structures tests cases,
- Making round robin exercises: confronting/comparing SPH methods available among partners by simulating laboratory and simple structures tests (and comparing to experimental results),
- Discussing about improvements and developments to better model fluid/structure interaction.

The work programme is divided into five Work Packages, each led by a Work Package Leader responsible for the final reporting of their corresponding task. Work Packages may be divided into sub-tasks, as described in section 2.2.

2.2 Work packages description

2.2.1 **WP1:** Review of existing methods to deal with fluid/structure interaction problems — **WP1 leader:** ONERA

Work Package 1 is concerned with the review of numerical methods available on fluid/structure interaction modelling. Data will be provided by partners, through their experience in using FE analysis tools and will concern all existing fluid modelling methodologies actually implemented in the commercial FE codes available within the project – Lagrange, ALE, SPH – and any simulation case (ditching of aircraft or helicopter, slamming, sloshing, bird strike…). The objective is:

- To draw the state-of-the-art in the field of fluid/structure interaction modelling and achieve a critical analysis of available tools according to the simulated case, physical phenomena involved, loading conditions, …
- To highlight and clarify the advantages/limitations of the SPH method compared to other methods.

This WP will be performed within the KICK-OFF meeting of the Action Group and would consist in compiling, into the minutes, information provided by partners.

Contributing partners	All

2.2.2 WP2: Generation and circulation of experimental database for the benchmarking of fluid/structure interaction analysis tools

WP2 leader: CIRA

WP2 aims at collecting and generating experimental data to be used in WP3 in order to evaluate/validate numerical tools. This Work Package is a crucial issue for the project, as most numerical activities depend on it.

Tests to be considered must be accurate, repetitive and performed with perfectly controlled testing conditions in order to permit clear comparisons with numerical results. Furthermore, the main focus of the project being dedicated to the fluid modelling and its interaction with the structure, the latter must be simple enough to minimize calculation costs and/or avoid numerical problems. This will permit to perform numerous simulations focused on the fluid modelling (especially making parametric studies to really assess the method).

Experimental data of interest for the project have been classified in 2 main categories:

- **Laboratory tests**: Structures interacting with the fluid must be very simple and easy to model. Tests must permit to focus on the fluid formulation and fluid equation of states and avoid numerical modelling problems not directly linked with the fluid (coming from the symmetry cinematic conditions – which generate problems in SPH -, the wave reflection at the boundaries of the fluid…).
- **Tests on simple structures**: tests are conducted on low-scale structures, fully rigid and deformable, that may be typically of spherical, cylindrical or dihedral shape. These tests may permit to study specific topics (ex: air cushion, fluid entry into the tested structure) and different impact conditions (low angle impact, forward speed, impact on non-flat fluid surface - waves)

Tests on more complex or full-scale structures are not considered in this WP due to their inherent cost and the difficulties they involve in terms of meshing development.

WP2 is divided into 3 sub-tasks, the first one dedicated to a review on existing experimental data (laboratory tests and tests on simple structures) in order to start WP3 as soon as possible, the second one to the definition and performance of additional laboratory tests and the third one to the definition and performance of additional tests on simple structures. These 2 last sub-tasks will depend on the available data collected in the first sub-tasks; tests to be performed will be defined in close interaction with partners involved in WP3.

WP2.1) Review and circulation of existing data

- **Laboratory tests: impact of droplets onto a pressure transducer (ONERA)**

ONERA will provide experimental results on droplet impact tests performed within a PhD study (2000-2003): « Contribution to the analysis of fluid/structure interactions for water impacts » - PORTEMONT Gérald. Tests consisted in impacting single pressure transducer (considered as the test specimen - no bias coming from the measurement equipment is therefore introduced as the tested structure is the measurement device) with droplets and accurately analysing pressure measurements. The experimental set-up is presented in the following figure.

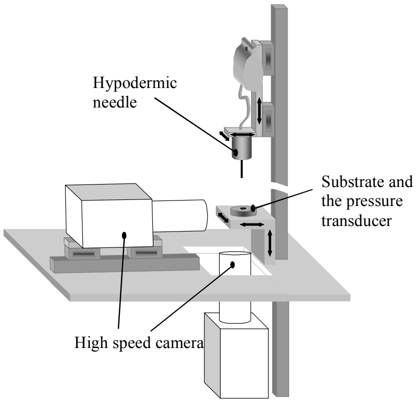


Figure 1: Experimental facility

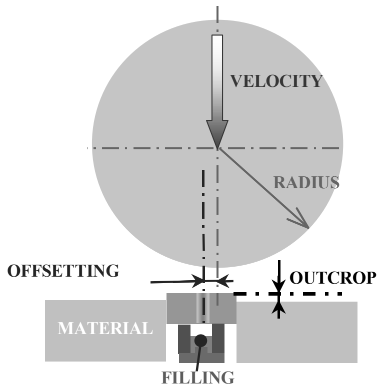


Figure 2: Investigated parameters

Water droplets were generated by different hypodermic needles in order to vary the droplet diameter from 3 to 5 mm. The temperature of the tested liquid was controlled by a thermocouple inserted inside the needle and droplets could be dropt from a height up to 2 m thus permitting to cover an impact velocity range from 0,5 up to 5 m/s.

A high-speed camera permitted in one hand to picture the droplet at the impact time in order to measure the initial test conditions (droplet diameter and velocity) and, in another hand, to record the evolution of the shape, the horizontal/vertical velocities and the splashing of the droplet along the test and relate it to the pressure measurements from the transducer.

Several parameters were investigated (see *Figure* 2):

- The impact velocity (between 1.2 and 5 m/s),
- The droplet radius (between 1.5 and 2.1 mm),
- The filling ratio of the transducer cavity (full of water, oil or air),
- The offset of the droplet (between 0 and 0.2 mm),
- The sensor outcrop compared to its support (between –0.1 and +0.1 mm),
- The substrate material (as the droplet diameter is larger than the transducer), which the pressure transducer was screwed on (plexiglas or aluminium).

Within the PhD study, only distilled water (well known properties) was used for the droplet (the fluid density influence was not investigated). A strong influence of the velocity, offset and especially the cavity filling ratio was observed. The latter parameter influence is shown in the following figure:

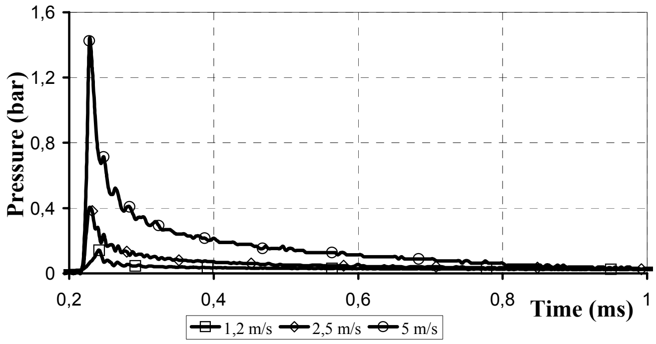


Figure 3: Impact pressure with the cavity full of water

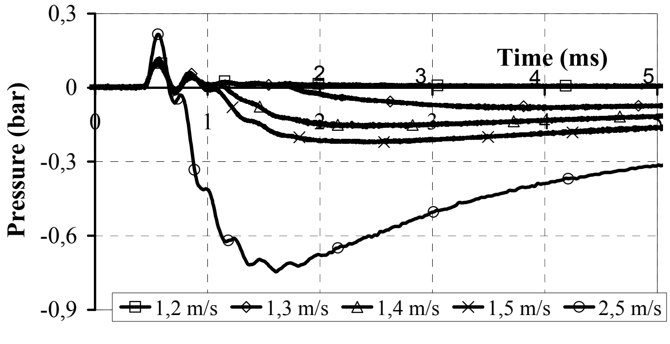


Figure 4 : Impact pressure with the cavity full of air

In the case of the transducer cavity full of water, the curve shape remains the same whatever the impact velocity (first peak pressure increasing with velocity and then decreasing until a stagnation pressure). In the case of the transducer cavity full of air, the pressure response strongly depends on the impact velocity, with a “negative” pressure peak depending on the impact velocity (result now physically explained).

Within the Action Group, 2 or 3 tests configurations will be selected (according to their interest in terms of modelling) and their results will be distributed to partners.

Contributing partners	ONERA: circulation of selected experimental results on droplet tests
Milestones	M2.1.1.: Selection and circulation of existing laboratory tests data

WP2.2) Additional testing on laboratory structures and circulation of data

- **Additional laboratory tests: impact of droplets (ONERA)**

Complementary to the provided database on droplet impact tests onto a pressure transducer, ONERA proposes to perform droplet impact tests onto a flat plate (∅20 mm for instance) fixed over a piezo-electric load cell to record the evolution of the impact force. The experimental set-up will be identical to the one used for tests with a transducer.

Another option would consist to perform droplet tests with a droplet fluid different from water (for instance oil) to evaluate the fluid density influence on the pressure evolution. Tests would be performed with parameters identical to those of tests selected in WP2.1 (impact velocity, filling ratio of the transducer cavity, offset, sensor outcrop, substrate).

- **Additional laboratory tests: impact of droplets at higher impact velocities (Imperial College)**

Imperial College proposes to supply water droplet impact data for impacts onto flat rigid/compliant specimens. The specimens will be mounted at the end of a long cylindrical bar (similar to a Hopkinson bar) which will be strain gauged and can be used to derive the resultant reaction force of the impact event for comparison with the numerical predictions. It is currently anticipated that the water droplet impact velocity will be at 100-150m/s with a high-speed camera used for the impact event. The structural material and the relevant water droplet diameter will be selected within the Garteur Group.

Contributing partners	ONERA: droplet tests on a flat plate or droplet tests on a transducer - study of fluid density Imperial College: droplet tests at higher impact velocities
Milestones	M2.2.1.: Definition of additional laboratory tests M2.2.2.: Circulation of additional laboratory tests results

WP2.3) Additional testing on simple structures and circulation of data

- **Water impact tests on simple <u>triangular</u> and <u>semi-circular</u> rigid structures (Politecnico di Milano):**

Politecnico di Milano will contribute by performing tests similar to those performed within the Brite Euram Project CAST (FW5 - 2000/2003) i.e. mainly water impacts tests on existing simple specimens (triangular and semi-circular section).

The two available specimens (*Figure 5*) are made of 20 mm thick plywood plates, covered with glycol-reinforced glass-fibre of 3 mm thickness (detailed construction drawings, including the location of the pressure transducers, are available). Within the CAST project, in addition to the pressure transducers distributed in the surface of the two shapes, accelerometers were placed on either side of the specimen.

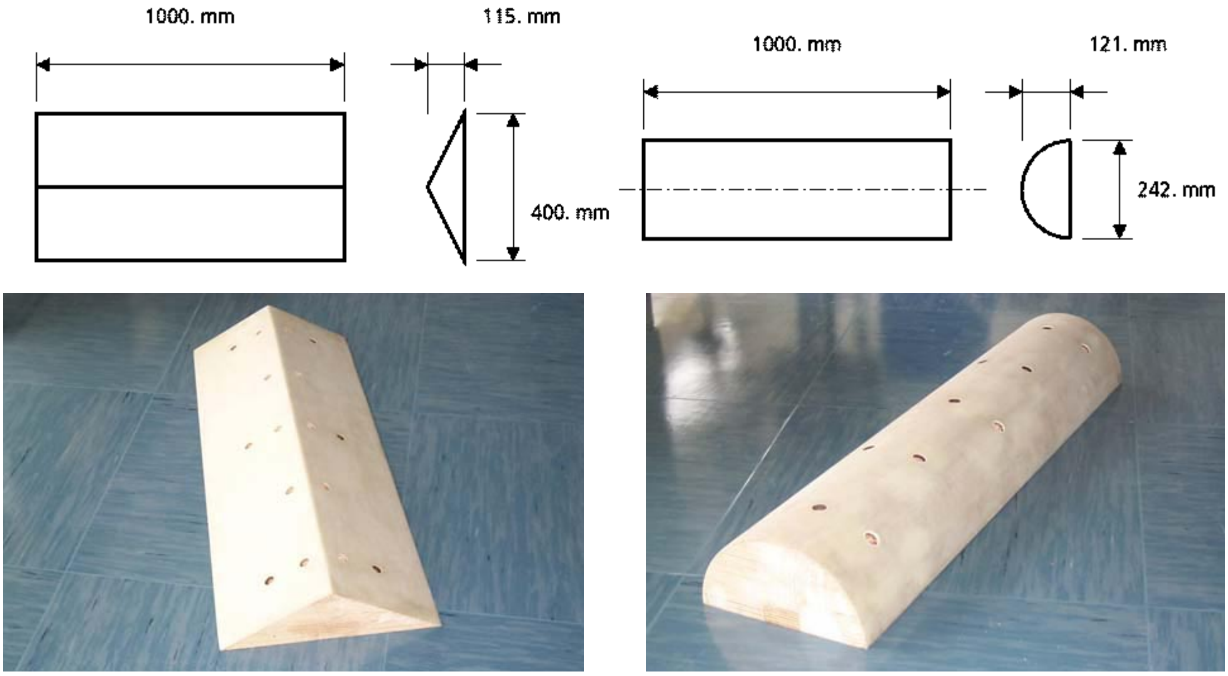


Figure 5: Principle dimensions of the two Glass-fiber reinforced plywood shapes tested within the CAST project

Compared to the tests conducted within the CAST project (which raised difficulties to interpret the pressure signals), the new contribution will consist in:

1) Using different transducers with the same location,

2) Using "pressure belts" to acquire the pressure shape of a strip of specimen instead of measuring it at discrete points, which will permit to verify the theoretical pressure field that can present strong changes between adjacent points but should maintain the same global shape.

3) Making impacts with vertical velocity but imposed attitude (for example 5°-10°-20°).

- **Water impact tests on simple semi-circular <u>rigid</u> and <u>deformable</u> structures (CIRA):**

CIRA will contribute to the generation of experimental database performing two water impact tests on a rigid body and on a simple deformable metallic structure. The water impact tests will be performed by means of a vertical drop tower, whose description is provided in the following figures, located on the side of the available water pool. The following impact conditions will be achieved:

- Vertical velocity 8 m/s,*
- Attitude 0,0,0

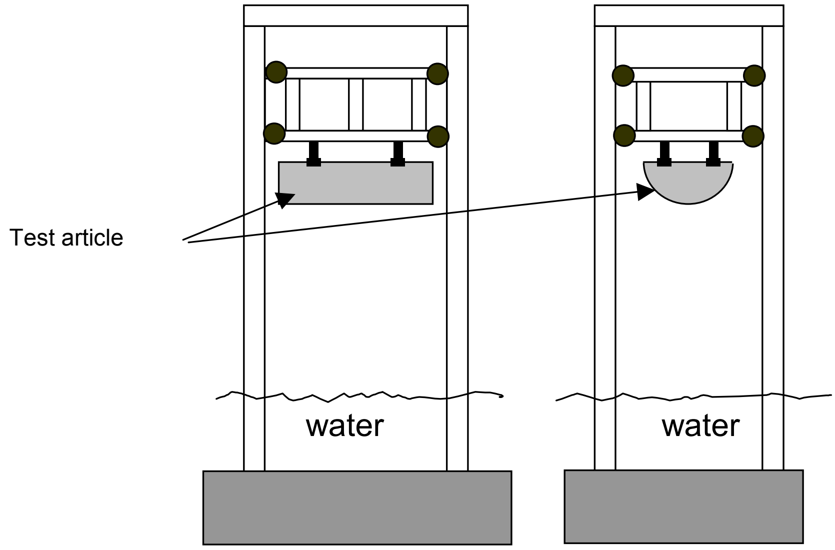


Figure 6: drop tower description

The test articles are two metallic structures with semi–circular shape, one having a rigid impact surface and one with a deformable impact surface made out of an Aluminium sheet. Details of the construction will be provided later. The length of test article is 1.60 m and the radius is 0.5m.

The tower is shown in *Figure 7* (in the picture, the pool is shown empty). The structure is made out of steel. The tower is 11 meters high. The test specimen will be attached to the trolley that will be free to slide down by gravity. The tower has been installed in the CIRA's pool for ditching test.

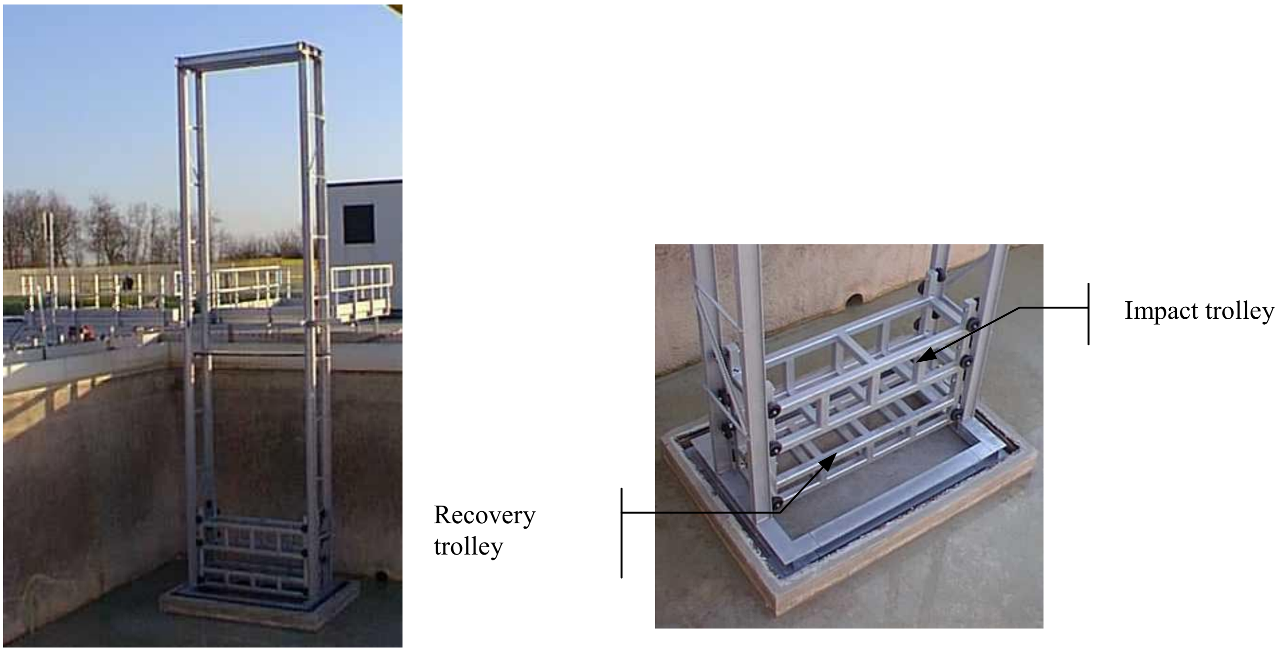


Figure 7: a) Test Rig, b) trolleys

Water level is 4 meters above the bottom of the pool. Another trolley is sitting at tower footing and can be raised after testing to recover test article and impact trolley (see *Figure 7*).

The release system is remotely activated. After releasing, impact trolley trajectory is guided thanks to a wheel assembly while the attitude is obtained securing in the desired manner the test article to the impact trolley.

Velocity at impact is measured by an optical system. After impacting the water surface the trolley/test article complex is stopped by contact of the side frames on the recovery trolley, a gap between the trolleys is left so that no further deformation occurs to the test article for impacting with the recovery trolley.

The tower will be more than suited for the specific tests foreseen. The following data are, in fact, providing the tower specification which area in compliance with test requirements.

- test article weight: up to 2 ton,
- test article size: 2 x 2 m²,
- Impact velocity: up to 10 ÷15 m/s,
- Impact surface: water pool (100 x 22 x 5 m^3).

CIRA proposes to instrument the test articles with 9 pressure transducers, 9 strain gauges and 3 accelerometers. The location of the sensors is shown in the sketch. The strain gauges are located in the same location of pressure transducer, but on the inner surface.

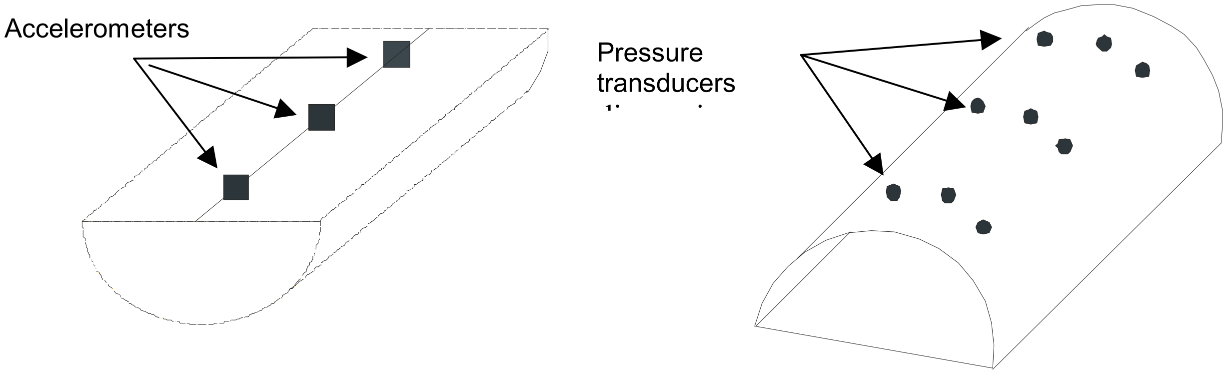


Figure 8: Instrumentation

The data will be collected at 10 KHz and filtered by a CFC 1000 SAEJ211 filter. The tests will be recorded by 2 High Speed cameras at 1000 fps.

Contributing partners	Politecnico di Milano: Water impact tests on simple triangular/semi-circular rigid structures CIRA: Water impact tests on simple semi-circular rigid/deformable structures
Milestones	M2.3.1.: Definition of additional tests on simple structures M2.3.2.: Circulation of additional tests results on simple structures

2.2.3 **WP3:** Round robin exercises with SPH and other methods available among partners / comparison of results

WP3 leader: Cranfield University

The aim of Work Package 3 is to perform round robin activities with fluid/structure interaction analysis tools available among partners, by modelling experimental tests provided in WP2 and comparing numerical results thus obtained in order to identify the capacities or limitations of such tools and help defining developments for WP4. Though the overall objective of the project regards the SPH method, the Exploratory Group finds worthwhile to also consider any fluid/structure interaction method capable of dealing with complex fluid/structure interactions (ex: water ingress through the failed structure during ditching), in order to evaluate if and how far the SPH method can be considered as the most competitive solution to deal with helicopter ditching. Considering that the Lagrange or Arbitrary Lagrange Euler formulations, as actually implemented in most commercial codes, are not concerned (not capable of dealing with complex fluid/structure interactions), this actually concerns :

- A new Euler Lagrange Coupling method (so called ELC) implemented in LS-DYNA and commercially available for LS-DYNA users (LML),
- An alternative “non-SPH” meshless method (not existent in literature but currently under development by ESI Group).

Numerical activities of WP3 are therefore divided into 4 sub-topics:

- Simulation with SPH method and comparison with tests: Works may especially target at investigating the contact interface between the particles and the structure, studying the boundary condition and the outlets particles, investigating the capacity to model air cushion, cavitation…
- Simulation with “ELC” method and comparison with tests,
- Simulation with alternative “non-SPH” meshless methods and comparison with tests,
- Code comparisons.

Tests provided within WP2 only concern low-scale structures; the project targeting at improving methods for application to helicopter ditching, it is also planned to model full-scale structures, in order to evaluate the capacities of analysis tools to handle with industrial problems (especially regarding CPU costs). This will also enable to draw guidelines and recommendation for using the SPH method, applied to helicopter ditching (model size, mesh density…). In order to minimize the modelling complexity of the structure, the considered full-scale structure(s) will be simplified – fully rigid or locally deformable. Their geometry will be defined within the Action Group. As no experimental data will be associated, only code comparison will be performed. Non-standard impact conditions (impact with a forward speed, impact on waves) may also be studied.

WP3.1) Simulations of tests on laboratory structures

Laboratory tests conducted within the PhD study of PORTEMONT were associated to numerical analysis aiming at evaluating fluid/structure interaction modelling methods available in the Radioss code. Within this numerical phase, a volume FE model of the pressure transducer, including all relevant material characteristics (especially the membrane ones), was developed and evaluated (the pressure measured by the transducer is calculated from the membrane deformation, as in the real sensor). Most efforts concerned the Lagrange and ALE modelling and only one model configuration (transducer cavity full of water, impact speed: 5 m/s, offset=0 ➔ axis-symmetrical model) involving a SPH modelling of the droplet was finally studied (see following figure).

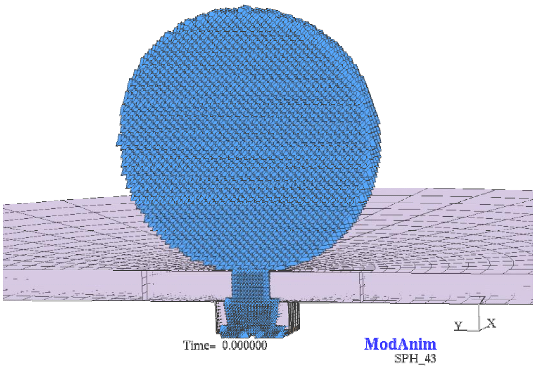


Figure 9: FE model of the pressure transducer with a SPH modelling of the droplet

In order to start WP3.1 as soon as possible, the numerical model of the structure (the transducer) will be provided to partners involved in WP3.1 (the modelling of the droplet will be left to the responsibility of each partner).

Test configurations to be modelled (droplet diameter, impact speed…) are those selected and distributed within WP2.1; the share between partners will be defined within the Action Group.

Contributing partners	**Simulation with SPH method / comparison with tests / code comparison** ONERA DLR MECALOG Cranfield University Imperial College Politecnico di Milano (Simulations using LSTC LS-Dyna 970 commercial version) **Simulation with "ELC" method / comparison with tests / code comparison** LML **Simulation with "non-SPH" meshless method / comparison with tests / code comparison** ESI
Milestones	M3.1.1.: Work share between partners

WP3.2) Simulations of tests on simple structures

The share between partners of tests on simple structures to model (produced within WP2.3) will be defined within the Action Group. In order to focus works on the fluid modelling, the WP will start by defining a common FE model for the structures (the modelling of the fluid will be left to the responsibility of each partner).

Contributing partners	**Simulation with SPH method / comparison with tests / code comparison** ONERA DLR MECALOG Cranfield University Imperial College Politecnico di Milano (Simulations using LSTC LS-Dyna 970 commercial

	version) **Simulation with "ELC" method / comparison with tests / code comparison** LML **Simulation with "non-SPH" meshless method / comparison with tests / code comparison** ESI
Milestones	M3.2.1.: Selection of test configurations to be modelled and work share between partners M3.2.2.: Definition of the structures meshing

WP3.3) Simulations on complex/generic structures for code comparison

The geometry of the generic structure and the impact configuration to be modelled will be defined within the Action Group and a common FE model of the structure will be produced (the modelling of the fluid will be left to the responsibility of each partner).

Contributing partners	**Simulation with SPH method / code comparison** Cranfield University DLR EUROCOPTER (will contribute to the design of generic FE models (rigid & deformable) and will perform ditching simulations using RADIOSS (SPH)) MECALOG Politecnico di Milano (Simulations using LSTC LS-Dyna 970 commercial version) **Simulation with "ELC" method / code comparison** LML **Simulation with "non-SPH" meshless method / code comparison** ESI
Milestones	M3.3.1.: Definition of the complex/generic structures and of the simulation configurations M3.3.2.: Definition of the structures meshing

2.2.4 **WP4** Improvement of SPH method, applied to helicopter ditching

WP4 leader: MECALOG

WP4.1) Discussions/developments/implementation

Based on the outputs of WP3, the objective of WP4.1 is to discuss and define developments likely to improve SPH method, with respect to helicopter ditching. According to the level of efforts proposed by partners (especially code developers), developments will be implemented in the available codes. WP4 will be undertaken in parallel to WP3, so as to evaluate developments of WP4 within WP3.

Different sub-topics of interest can be defined, all targeting at improving the SPH method.

- Improvement of the SPH formulation,
- Improvement of the SPH environment (contact interface between the particles and the structure, SPH boundary condition, influence of mesh density and mesh networks, outlets …post-treating….)

- Improvement of the fluid EOS (viscosity, cavitation, incompressibility…)
- Reduction of CPU cost

Contributing partners	MECALOG Cranfield University LML ESI

WP4.2) Recommendations to model fluid/structure interaction with SPH method

Contributing partners	ONERA MECALOG Cranfield University LML DLR EUROCOPTER (will express the user's views on SPH results with respect to helicopter industry requirements) ESI

2.2.5 **WP5:** reporting and management **WP5 leader:** ONERA

Reporting consists in:

- One Work Package report for each Work Package, written and distributed by each WP leader in the month following the end of their Work Package,
- One Final report by the chairman edited and distributed at the end of the Action Group

In addition, each partner is encouraged to produce a short summary report describing their main results and conclusions at the completion of their involvement in each task, as well as technical notes to exchange detailed data during the project.

Contributing partners	ONERA, CIRA, Cranfield University, MECALOG (management) All partners (reporting)

2.3 Expected achievements

The first outputs of the Action Group are:

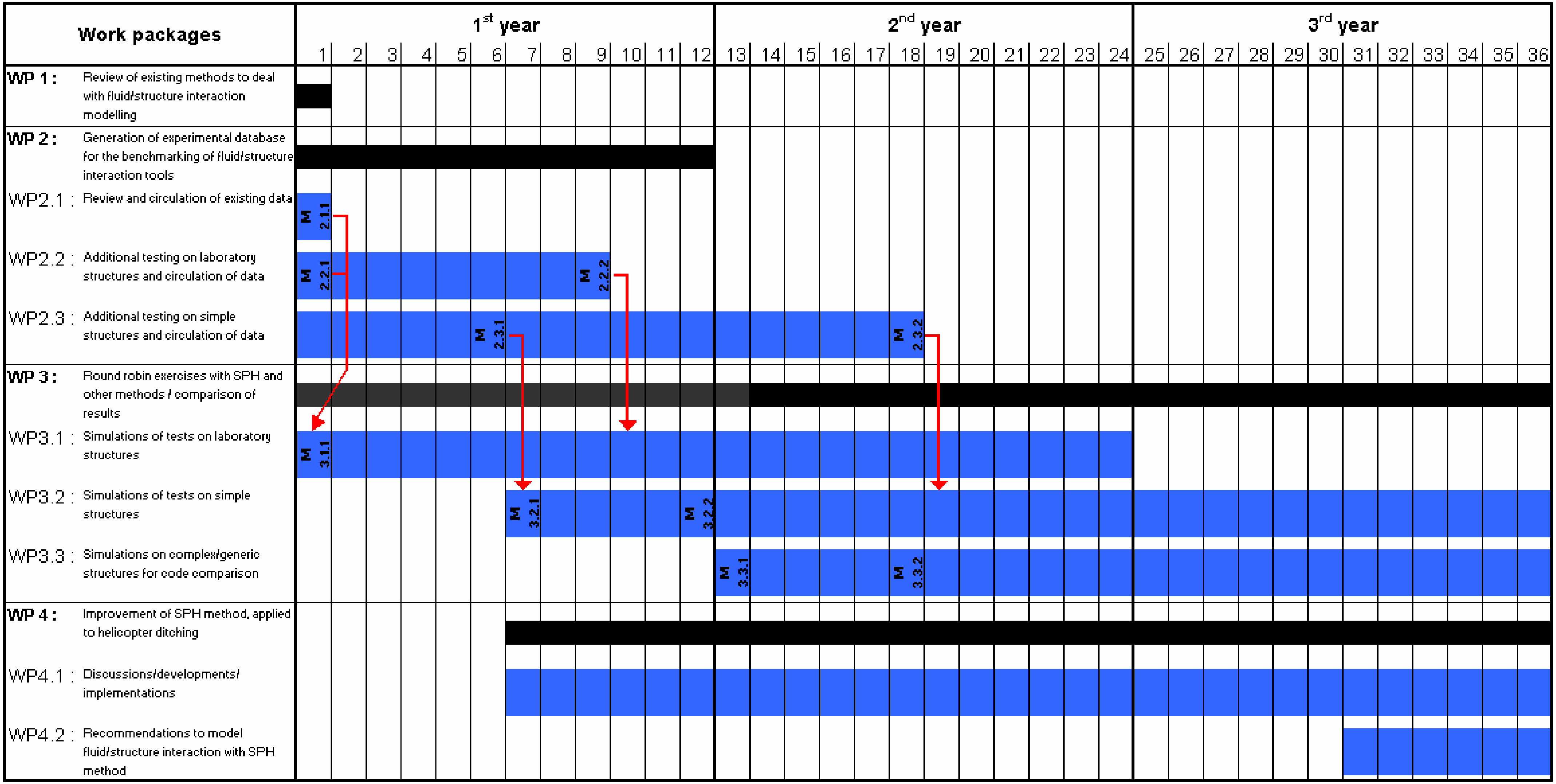
- To provide the scientific community with an experimental database on water impact tests, usable for fluid/structure interaction tools validation,
- To increase the level of confidence of SPH method for the modelling of fluid/structure interaction,
- To define guidelines regarding the use of SPH method, for application to the modelling of helicopter ditching.

A second output would be to take benefit of the experience gained within the Action Group to organise and propose a new European project, dealing with fluid-structure interaction modelling, within the 6^{th} or 7^{th} PCRD.

2.4 Timetable Milestones and bar chart

The proposed duration for the action group is 3 years, with an expected starting date and kick-off meeting in end 2004/beginning 2005.

The bar chart on next page shows the scheduling of Work Packages, with their corresponding milestones. Although some activities may have to follow on from some others, most works shall be performed concurrently when possible.


Work packages
1st year
2nd year
3rd year
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36
WP 1 : Review of existing methods to deal with fluid/structure interaction modelling
WP 2 : Generation of experimental database for the benchmarking of fluid/structure interaction tools
WP2.1 : Review and circulation of existing data
WP2.2 : Additional testing on laboratory structures and circulation of data
WP2.3 : Additional testing on simple structures and circulation of data
WP 3 : Round robin exercises with SPH and other methods / comparison of results
WP3.1 : Simulations of tests on laboratory structures
WP3.2 : Simulations of tests on simple structures
WP3.3 : Simulations on complex/generic structures for code comparison
WP 4 : Improvement of SPH method, applied to helicopter ditching
WP4.1 : Discussions/developments/ implementations
WP4.2 : Recommendations to model fluid/structure interaction with SPH method
M 2.1.1
M 2.2.1
M 2.2.2
M 2.3.1
M 2.3.2
M 3.1.1
M 3.2.1
M 3.2.2
M 3.3.1
M 3.3.2

2.5 Summary of partners technical contribution and resources

The following table summarises partner's contributions with the associated Man-Month resources.

Partners	**WP1** Review	**WP2** Tests database generation			**WP3** Benchmark activities			**WP4** SPH improvement		**WP5** Reporting and management	**Total** MM Allocation
		WP2.1	WP2.2	WP2.3	WP3.1	WP3.2	WP3.3	WP4.1	WP4.2		
CIRA				3						2	5
Cranfield University					3	3	3	34	6		49
DLR	1				3	2	3		1	2	12
ESI					0,5	0,5	1	0,75	0,25		3
Eurocopter							3		1	0,5	4,5
Imperial College	0,5		3		2	2				2	9,5
LML	1				1	1	1	1	1	2	8
Mecalog / Eurosim	1				2	2	2	1	1	1	10
ONERA	1	1	1		2	2			1	4	12
Politecnico di Milano	1			6	2	2	2			2	15
Total MM allocation	5,5	1	4	9	15,5	14,5	15	36,75	11,25	15,5	**128**

Other expenses are listed below:

Partners	**Durable equipments** (kEuros)	**Consumables** (kEuros)	**Travel** (kEuros)	**Computing** (kEuros)
CIRA	0	25	3	28
Cranfield University	2	6	14	10
DLR	2	5	10	9
ESI			3	
Eurocopter			15	10
Imperial College	1	1	7	10
LML			10	10
Mecalog / Eurosim			5	10
ONERA	2	5	10	10
Politecnico di Milano	6	4	8	6
Total	13	46	85	103

3 Partnership and management

3.1 Partnership

The partnership is mainly based on the CAST consortium and therefore benefits from a recent cooperation experience. It comprises 1 helicopter industrial manufacturer, 2 private software developers, 3 research institutes and 4 universities (see following list), ensuring a quite balanced share between the industrial, research and academic worlds. The contact details are listed below.

Company	Representative	Phone Fax	E-mail address
CIRA - Centro Italiano Ricerche Aerospaziali SC pa Via Maiorise (CE) Capua, ITALY	Ludovico VECCHIONE	+39 0823 623918 +39 0823 969272	l.vecchione@cira.it
Cranfield University Cranfield Bedfordshire MK43 0AL, UK	Rade VIGNJEVIC	+44 (0) 1234 754736 +44 (0) 1234 752149	v.rade@cranfield.ac.uk
DLR - Deutsches Zentrum fur Luft-und Raumfahrt Pfaffenwaldring 38-40,D-70569 Stuttgart,GERMANY	Nathalie PENTECOTE	+49 (0) 711/6862-564 +49 (0) 711/6862-227	nathalie.pentecote@dlr.de
ESI - Engineering System International France 99 rue des Solets, Silic 112, 94513 RUNGIS CEDEX, FRANCE	Argiris KAMOULAKOS	+33 (0) 1 49782800 +33 (0) 1 46877202	aka@esi-group.com
EUROCOPTER Structural Resistance – OTCS /M Aeroport de Marseille-Provence F13725 - MARIGNANE-Cedex, FRANCE	Vincent Lassus	+33 (0)44285 9390	vincent.lassus@eurocopter.com
Imperial College of Science, Technology and Medicine Department of Aeronautics Room RODH 354B PRINCE CONSORT ROAD, SOUTH KENSINGTON, LONDON, UK	Lorenzo IANNUCCI	+44 (0)20 7594 5058 +44 (0)20 7584 8120	lo.iannucci@imperial.ac.uk
LML - Laboratoire de Mécanique de Lille Avenue Paul Langevin 59655 Villeneuve d'Ascq Cedex, France	M'hamed SOULI	+33 (0)3 20 33 71 76 +33 (0)3 20 33 71 53	mhamed.souli@univ-lille1.fr
Mecalog / Eurosim Toulouse Chez CTA 12 avenue de l'Europe 31520 Ramonville	Jean-Baptiste MOUILLET	+33 (0)5 61 75 44 01 +33 (0)5 61 75 17 98	jbmouillet@mecalog.fr
ONERA/Centre de Lille - Office National d'Etude et de Recherche Aéronautique 5 Bd Paul Painlevé 59045 Lille Cedex, France	David DELSART	+33 (0)3 20 49 69 35 +33 (0)3 20 52 95 93	David.Delsart@onera.fr
Politecnico di Milano Via La Masa 34 20158 MILANO ITALY	Luigi-M L CASTELLETTI	+39 02 2399 7155 +39 02 2399 7153	Luigi.Castelletti@polimi.it

3.2 Management

Chairmanship: ONERA (D. Delsart) is proposed to assume the chairmanship of the Action Group, and the LML (M. Souli) the vice-chairmanship.

Project Monitoring: Mr François Toulmay from EUROCOPTER is in charge of the monitoring of the Action Group.

3.3 Meetings

Meetings will be held every six months to assess progress and report the technical advancement to the Helicopter GoR. Minutes will be produced for each meeting, including a copy of presentations provided by partners and describing their achievement over the considered period.

4 Reporting, Publications and dissemination

Reports produced by the Action Group will be unclassified, but will have a limited distribution in accordance with a distribution list agreed amongst partners and included in the Annex of the present document. Reports will be marked “GARTEUR limited”. Members will be free to report their own work in accordance with their national and organisation policies.

Publications at conferences or in Journals will require the prior permission from partners of the Action Group.

A web site dedicated to the present Garteur Action Group may be set up if partners deem it to be beneficial and if suitable material and information are available.

5 Security and intellectual property rights

All background and foreground information will be treated according to Appendices A and B to MoU: “Rules for the Protection of Intellectual Property Rights” and “GARTEUR Security Regulations”.

APPENDIX: DISTRIBUTION LIST

Country	Person	Company
France	D. Delsart	ONERA
	E. Deletombe	ONERA
	R. Ortiz	ONERA
	P. Geoffroy	ONERA
	G. Haboussa	ONERA
	T. Khan	ONERA
	J.J. Philippe	ONERA
	M. Souli	LML
	F. Toulmay	Eurocopter OTRA/M
	V. Lassus	Eurocopter OTCS/M
	A. Kamoulakos	ESI
	J.B. Mouillet	MECALOG/EUROSIM
Germany	N. Pentecote	DLR
	C. Kindervater	DLR
	A. Johnson	DLR
Italy	L. Vecchione	CIRA
	M. Ignarra	CIRA
	S. Alguadich	CIRA
	M Anghileri	Politecnico di Milano
	L-M L Castelletti	Politecnico di Milano
	F Invernizzi	Politecnico di Milano
	M Mascheroni	Politecnico di Milano
United Kingdom	Rade Vignjevic	Cranfield University
	James Campbell	Cranfield University
	L. Iannucci	Imperial College London