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The scientific legacy of Roland Glowinski / *L'héritage scientifique de Roland Glowinski*

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Avant-propos du numéro spécial des Comptes Rendus Mécanique à la mémoire de Roland Glowinski

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Our dear colleague, Roland Glowinski, passed away on January 26, 2022, at the age of 84. He was not only a visionary applied mathematician, famous around the world for his numerical methods and algorithms, but also a wonderful friend. He was a member of the French Academy of Sciences and, as such, a member of the editorial board of its journal, *Comptes Rendus Mécanique*. The present special issue of the *Comptes Rendus Mécanique* is dedicated to honor his memory, his outstanding work and profound impact on our community. The contributions of this special issue are close to the favorite topics of Roland Glowinski: discretization of linear and non-linear partial differential equations, complex fluids, scientific computing, control and optimization algorithms, domain decomposition, operator splitting, modelling and simulation for mechanical, physical, biological and engineering applications.

Roland Glowinski was an alumni of the Ecole Polytechnique in Paris and held a PhD in mathematics from Paris VI University (nowadays Sorbonne University), prepared under the supervision of Jacques-Louis Lions. After an early career at the French Television Network, he was appointed professor at Paris VI University in 1970 and took over in 1976 the direction of the scientific computing laboratory of IRIA (now INRIA). He quickly became known worldwide as the best designer of algorithms for continuum mechanics problems; it earned him numerous appointments as scientific advisor including a position as director of CERFACS in 1992-1994. In 1985 he moved to the University of Houston where he was a Cullen Professor of Mathematics. He was an adjunct professor at several universities, including Jyvaskyla University in Finland

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Figure 1. Roland Glowinski (Credit: Chris Watts, University of Houston)

and Rice University in Houston. Roland Glowinski was a prolific writer, author of six books and around 380 articles. He received many awards and honors, including the Seymour Cray prize, Marcel Dassault prize, the W.T. and Idalia Reid prize, and his membership in the French Academy of Sciences, the French Academy of Technology and the Academia Europaea. The spectrum of Roland's scientific contributions is vast and intricate. Let us try to describe his main contributions.

His seminal work on domain decomposition algorithms stands as a testament to his pioneering spirit. He was the first to understand the links between Schwarz algorithms and Lagrange multipliers and thus propose methods without domain overlap. He is also the first to use the formalism of mixed formulations for these problems. He created the famous annual conference Domain Decomposition Methods. He earned the Cray prize in 1988 for this work. Roland was also instrumental in the development of efficient algorithms for fictitious domain methods in Lagrangian formulation. Following earlier ideas from the Russian school he proposed an appropriate functional framework which allowed him to analyze a convenient finite element discretization method to deal with time-dependent geometry problems on a single fixed mesh and prove error estimates.

In the realm of fluid dynamics, Roland's ideas led to the development of robust preconditioners for the Navier–Stokes equations, discretized by finite element methods. In his book on numerical methods for non-linear variational problems Roland Glowinski proposed iterative algorithms (conjugated gradients) with preconditioning for the generalized Stokes problem, thus opening the way to modern intensive computing as it is practiced today. Roland was the first to give a mixed formulation for the biharmonic problem, relying merely on low degree finite elements, which were at the time the fastest methods for calculating viscous flows. These methods were implemented at Dassault Aviation and were a model of successful scientific cooperation. In this same cooperation Roland studied transonic flows for a potential compressible fluid and proposed one of the first discrete formulations of the entropy condition.

Variational inequalities were a favorite topic of Roland Glowinski who devised several fundamental algorithms for their numerical solution. In particular, he advocated the augmented Lagrangian formulation which turned out to be extremely efficient for various applications, including free boundary problems, non-linear structural mechanics and fluid mechanics. His work was extremely innovative in several respects. For example, he proposed a primal-dual iterative algorithm, known as Alternating Direction Method of Multipliers, which became extremely popular, not only among numerical analysts but also in other communities like optimization, imaging and learning. One striking application was the numerical simulation of thousands of solid balls suspended in a viscous fluid, discretized in a 3-d unstructured mesh method, still using a Lagrangian formulation.

Finally, Roland Glowinski made ground-breaking contributions in the numerical methods for the controllability of hyperbolic problems. Following the lead of Jacques-Louis Lions who introduced the Hilbert Uniqueness Method, he was the first to point out that standard numerical schemes do not converge for the controllability problem. Indeed, they do not provide a control allowing to connect a given initial state to a desired target. Roland gave the explanation (the appearance in the numerical scheme of spurious high frequencies, which interfere so that the group velocity of the discrete model may vanish or be small) and powerful remedies (a two-grid approach and filtering methods). Not only did he solve this hard problem but he also did it with great elegance and mastery, revealing a deep analogy with the mixed finite element methods for the Stokes system, a topic in which he was also a pioneer.

We had the great privilege of collaborating with Roland Glowinski, and we are very grateful to have known him and learned so much from him. This special issue of the *Comptes Rendus Mécanique* is a token of appreciation and admiration.