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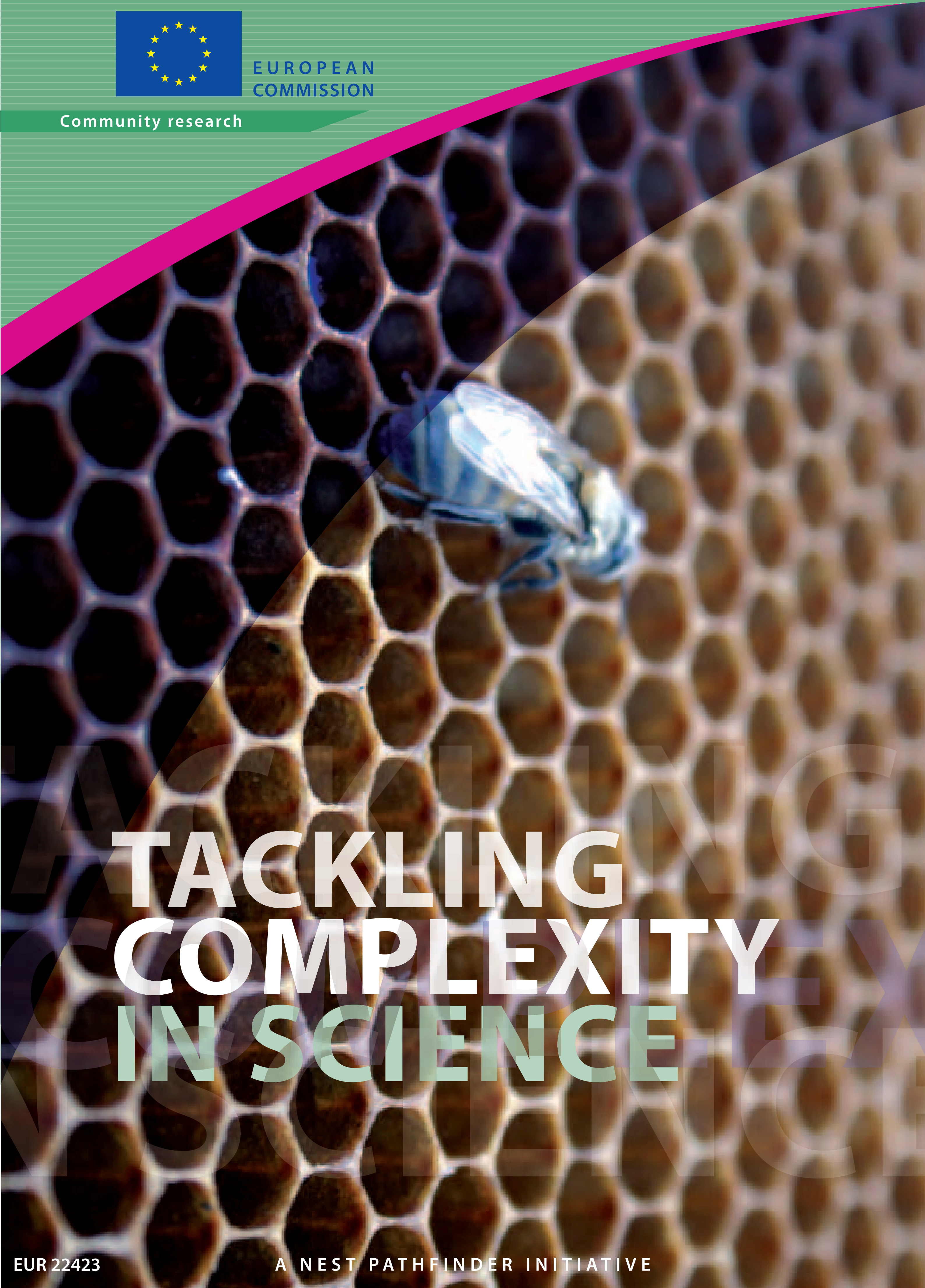

TACKLING COMPLEXITY IN SCIENCE

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A NEST PATHFINDER INITIATIVE

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FROM BREAKDOWNS TO EARTHQUAKES: IT'S A QUESTION OF SCALE

TRIGS

Natural catastrophes such as earthquakes, landslides and avalanches are triggered by perturbations. These perturbations have much in common with the disturbances that cause the failure of engineered structures. TRIGS is the first project to use the tools of complex systems analysis to explore triggering mechanisms across this wide scale range. As well as paving the way for improved geohazard forecasting, it will provide new methods for identifying weaknesses and mitigating breakdown of the infrastructures and devices that are essential to everyday life.

A landslide can be started by an earthquake; fatigue failure in an engine component can be induced by increased stress levels. While such effects occur over vastly differing spatial and temporal scales, the underlying causes are fundamentally similar. They, nevertheless, remain extremely difficult to explain and predict.

Natural disasters may also result from specific events: from precipitation and pore pressure variations; or from endogenous defects, ranging from chemomechanical deterioration and creep deformation to microcracking and microplasticity. Similarly, failure in engineering materials can be triggered by external environmental conditions: by mechanical, chemical or electromagnetic perturbations; or by internal causes related to relaxation of the structure through creep deformation, fracture or plastic flow.

Multiscale phenomena

The processes extend down to the atomic level, where the arrangement of atoms and the ensuing defects such as dislocations and microcracks are of crucial importance. And up to geological magnitude, where deformation instabilities manifest themselves in the form of extreme events, such as rockfalls, landslides, avalanches and earthquakes. But the response is invariably complex and non-linear.

One example of internal perturbation acting as a trigger is in wet snow avalanches, where surface warming and melt water production cause percolating water to be caught at capillary barriers, leading to a loss of shear support. Due to the complexity of the percolation in stratified snow cover, wet snow avalanches are notoriously difficult to forecast.

The aftershocks and landslides initiated by major earthquakes are among the many instances that can be cited of natural hazards triggered by external perturbations.

> **"TRIGS will develop more realistic modelling and allow greater accuracy in the forecasting of potential disasters than has so far been possible."**

A further complication is that, in most cases, several triggering mechanisms act simultaneously. This makes it necessary to address the interplay between different phenomena, adding further to the difficulty in understanding and predicting material failures and natural hazards.

New theoretical basis needed

Gaining a better insight will depend on the development of new theories that give the ability to bridge the scale ranges. This entails integrating methodologies from materials and earth sciences into the more general perspective of complexity. This requires a transfer of knowledge across traditionally separate disciplines.

Complex systems methodologies – from statistical characterisation of time series and spatial patterns to agent-based models, cellular automata and non-linear equations – have been applied over the past two decades to the modelling as well as assessment of natural hazards in geosystems. While several of the resultant models reproduce most properties of seismicity, the limited quality of the data, and limited knowledge of the Earth's crust rheology, have so far prevented the formulation of an 'optimal' seismic hazard model. Statistical tools and complex systems theory are now also used in materials science to understand fracture and plasticity, although this work is progressing at a slower pace than in the earth sciences.

The six institutes that make up the TRIGS consortium provide a balance of expertise that will facilitate cross-fertilisation between the two fields. The present need is to shift attention from the abstract, general thinking that is typical of complexity research, to a more quantitative, experimentally-based analysis.

The partners are approaching this issue by combining the statistical analysis of catalogued data and field measurements with laboratory experiments, multiscale materials simulations and non-equilibrium statistical modelling.

This European initiative draws on progress made in the different fields towards detailed modelling of materials and geosystems. Yet, at the same time, it will avoid the danger of neglecting system scale complexity because of an unwarranted attention to detail.

Instead of performing a global analysis of natural hazards, the team is using the basic framework of complexity theory and its associated models to study specific responses to well defined triggers.

From these findings, they will derive experimental strategies that allow for a quantitative assessment of system-specific parameters. The study of cross-scale interactions will enable new types of laboratory tests to be devised, delivering results that are more useful in understanding the triggering of instabilities in materials, devices and complete geosystems.

TRIGS will develop more realistic modelling and allow greater accuracy in the forecasting of potential disasters than has so far been possible. It will also contribute to better assessment and avoidance of the unforeseen consequences of human interference with the environment.

AT A GLANCE

Official Title
Triggering of Instabilities in Materials and Geosystems

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