

# CENTRE for STABILIZATION of PLANETARY EMERGENCIES

Control of Planetary Emergencies Using  
the Science of Complex Networks

NEW MANHATTAN PROJECT-  
SCIENCE FOR PEACE THE WORLD OVER

PROJECT 5- COORDINATORS: Profs. R. Schock/E.Schöll

# AGENDA

*Chairman A. Zichichi – Co-chair Robert N Schock*

Dr. Robert Schock

Center for Global Security Research, USA

*Why the Science of Complex Networks Fits in a New Manhattan Project*

Prof. Dr. Eckehard Schöll

Chair, Collaborative Research Center on Control of Self-Organizing Nonlinear Systems,  
and Institute of Theoretical Physics, Technical University of Berlin, Germany

*The Science of Complex Networks*

Prof. Keywan Riahi

Program Director, International Institute for Applied Systems Analysis, Laxenburg, Austria

*Integrated Assessment Modeling*

Dr. Michele Berlingerio

IBM Research, Ireland

*Smarter Urban Dynamics*

Dr. Sally Leivesley

Newrisk Limited, London, UK

*Catastrophic Risk and Security*

**\*DEBATE\***

**OBJECTIVES** – to model complex systems as networks of coupled non-linear, high dimensionality, dynamic elements

Applications - Power Grids, Internet, Transportation, Banking, Ecosystems, Social Structure, Neuronal, Security, etc.

*! Not sufficient to only understand the properties of network component parts to understand the system – now rely on intuition: system is too complex*

- unanticipated behavior of a large number of interacting components*
- components with collective dynamic behavior*

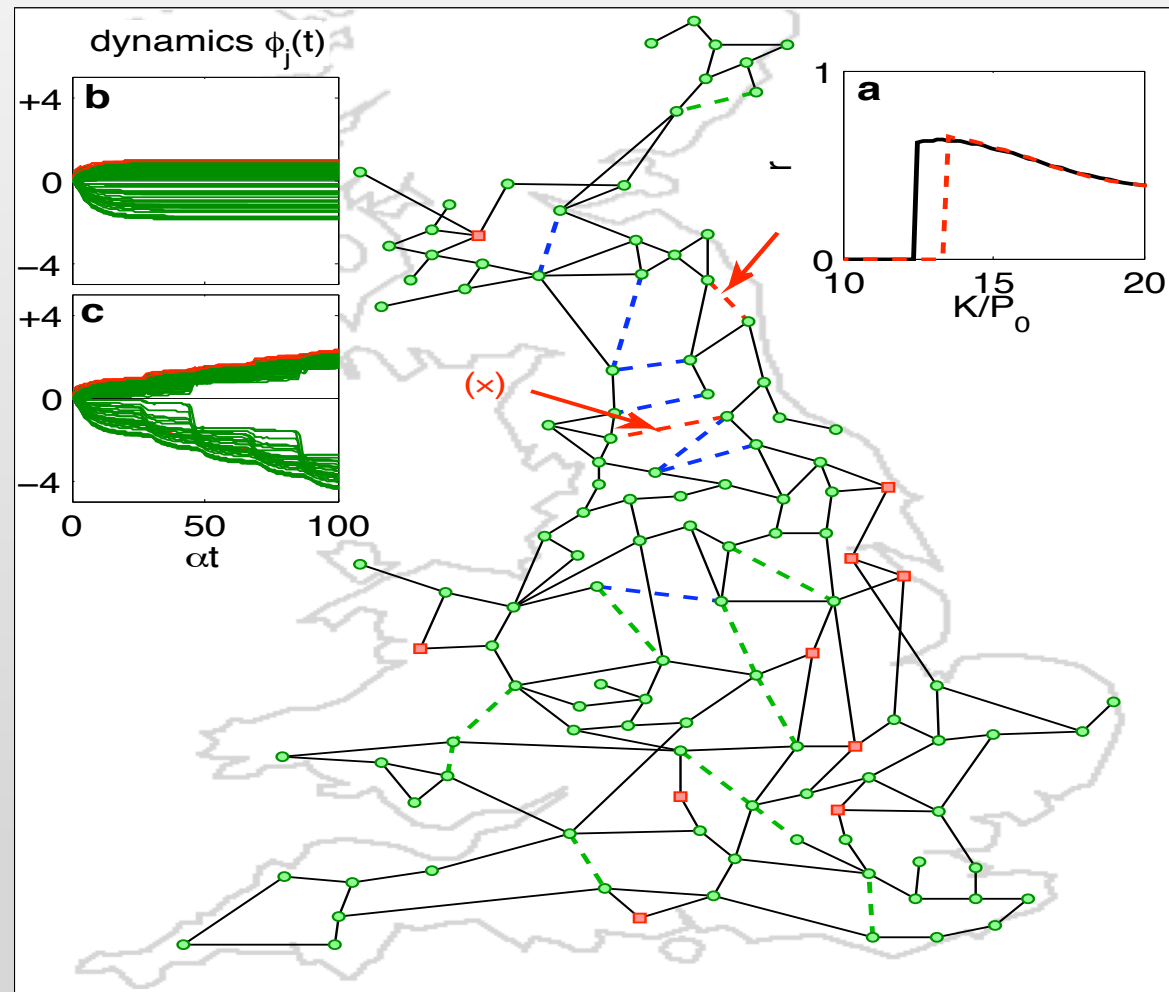
*Example* – elements or compounds in different phases & interactions are just as, or even more, important than the atoms themselves (e.g., carbon, water)

**IMPACT** – Breakthroughs to control very large interconnected networks with complex topologies & heterogenous components & using small perturbations to steer system

# Braess' paradox in complex networks?

Original Network

Add link:



Generators:  $P = 11P_0$

Consumers:  $P = -P_0$

Links:  $K = 13P_0$

Damping:  $\alpha = P_0$

D. Witthaut and M. Timme, New J. Phys. 14, 083036 (2012); Eur. Phys. J. B 86, 377 (2013)

Question now is –

“How to rationally control the dynamics” – A. Motter (2015)\*

Why? – development of smart self-healing systems and mitigation of failures all lead to control (management) and increased stability  
(hence Stabilization of Planetary Emergencies)

*“Physics stopped just looking at very small things and is being applied to big data”*

– May 2014 Workshop

Basic Physics: These trans-disciplinary methodological approaches to systems composed of many interacting parts are the same as used in basic physics

- this project adds a completely new facet to the traditional approaches used in elementary particle physics, and has a high potential for innovation with broad spin-off (even back to basic physics)

\* CHAOS 25, 097621, 2015

Networks: Have several structural properties in common

- heterogeneous distribution of # of connections per node (degree distribution)
- have a community structure (hierarchical or multilayer/multiplex topologies)
- many cases have relatively short path length (small world property)
- etc.

Control: Is dynamic

- have a large number of dynamic variables
- governed by nonlinear dynamics (possibility of non-invasive control)
- are dissipative (have attractors that can be targeted)
- can exhibit multiple stable states
- long-lived transients can be important
- are constraints on feasible control interventions
- operate in a decentralized way (respond sub-optimally to perturbations, but there are accessible states in which failures can be prevented)
- noise is inherent in the dynamics and in the parameters

**“Control” by an intervention to stabilize a state, create states and/or eliminate undesirable states**

# Example: A Very Important Complex System

## Energy End-Use Management

From ~9 sources to 1000s of usages (very complex network)

Stakes - ~\$300 B USD/yr in devices alone to use energy and overall 10x

Critical impact!

- cities have virtually all population growth
- >50% of GDP is from 22% of population in 600 cities
- water, food, sanitation, transport, security networks all

integrated with energy-use

Need - a holistic view of this very complex system

**Impact** - With potential solutions, engaging decision-makers on the understanding of a system or systems is likely

# **PROJECT ON SCIENCE OF COMPLEX NETWORKS**

## **Co-Directors**

**Eckehard Schöll** – Professor of Theoretical Physics, Technical University of Berlin

**Robert Schock** – University of California & World Energy Council retired

## **STEERING COMMITTEE**

**Adilson Motter** – Professor of Physics, Northwestern University

**Anna Nagurnay** – Professor of Super-networks, Operations and Information Management, U. Massachusetts Amherst

**Francesco Calabrese** – IBM Research, Ireland

**Dirk Witthaut** – Forschungszentrum Jülich, Germany

**Keywan Riahi** – International Institute for Applied Systems Analysis, Austria

**Santo Fortunato** – Aalto University, Helsinki

**Jie Sun** – Clarkson University, USA

**Sally Leivesley** – Director, Newrisk Ltd., U.K.

**Annette Sobel** – Professor of Medical Education, Texas Technical University

**[Nominee from among PMPs C-G in Phase II]**



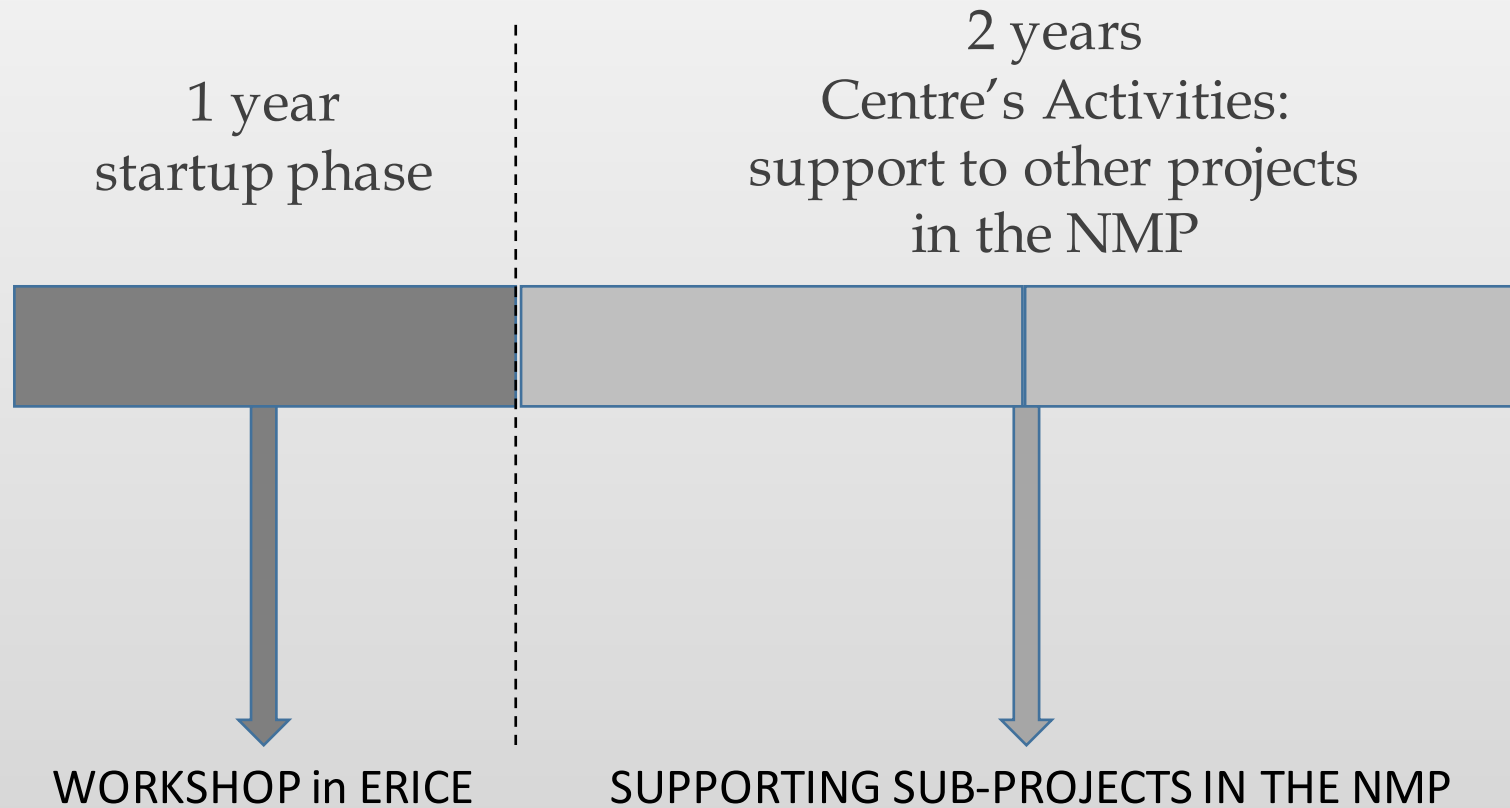
## WORK PROGRAMME

Phase I – Workshop in Erice identify priorities for subprojects (Early 2017)

### Phase II possible subprojects

- Urban Energy Optimization (2018)
- Terrorism & Electric Grid (2018)
- Water Infrastructure Network (mid-2018)
- Rapid Mitigation of Epidemics (2019)
- Agriculture and Food Supply (2019)
- Security of Information (2019)
- Eliminating Rural Poverty (2019)

# TIME FRAME & OBJECTIVES



# Budget (USD)

- WL – WFS            1.457.500
- Collaborators    3.296.000    [9.888.000]  
  (US/Germany/Industry: 5 [22])

# Centre for Stabilization of Planetary Emergencies

## **Key Workshop Questions**

1. What applications of CNC (Complex Network Control) can be applied to systems today? What sub-systems should be a priority and why?
2. Are there critical limitations of CNC? In all applications, or specific? What are they?
3. Going forward, what are the research priorities for CNC? (RD&D?) All or specific.
4. What tools do decision-makers and managers need to incorporate results?
5. What are next steps (immediate and intermediate) to move forward to overall goals and implementation?