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

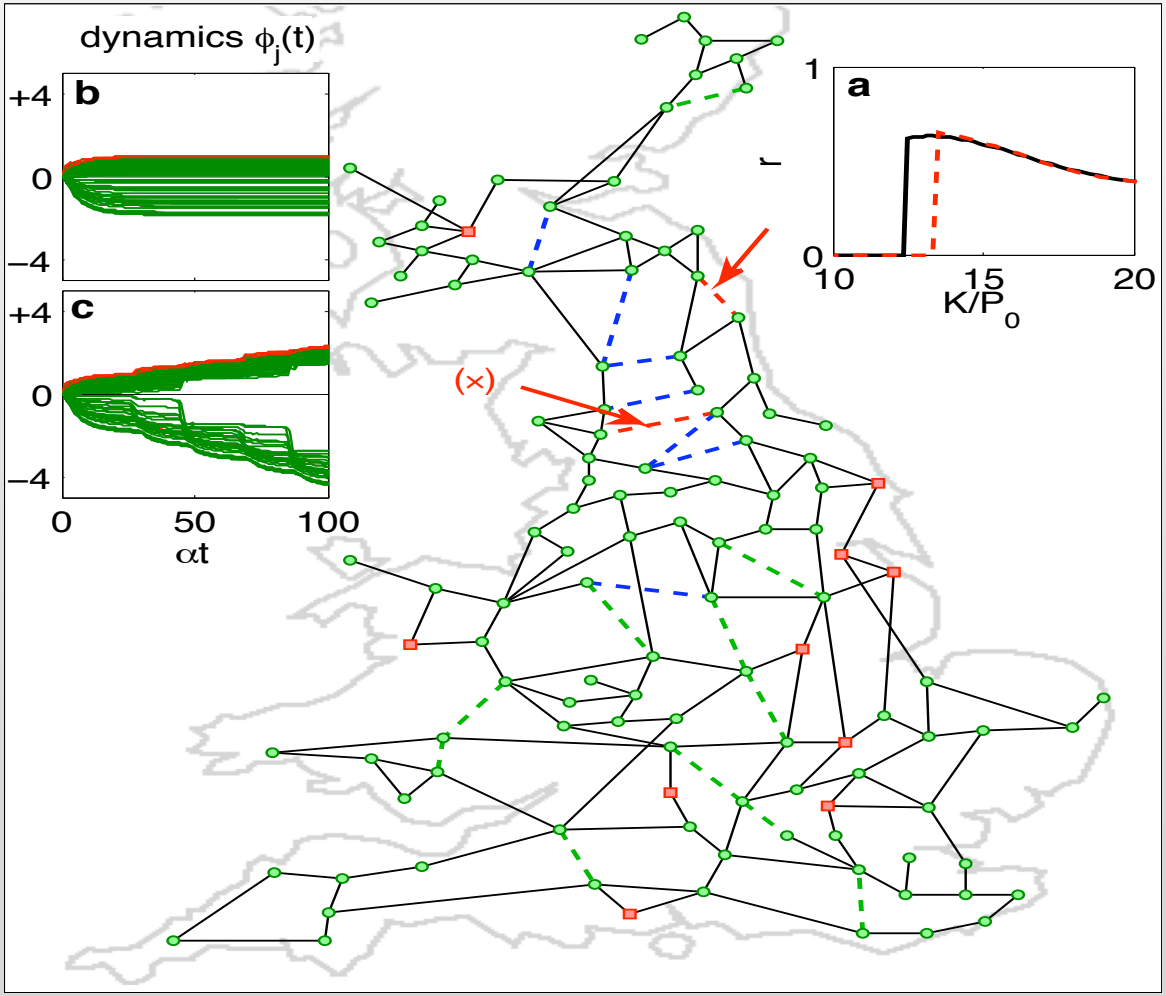
Example – elements or compounds in different phases & interactions are just as, or even more, important than the atoms themselves (e.g., carbon, water)

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

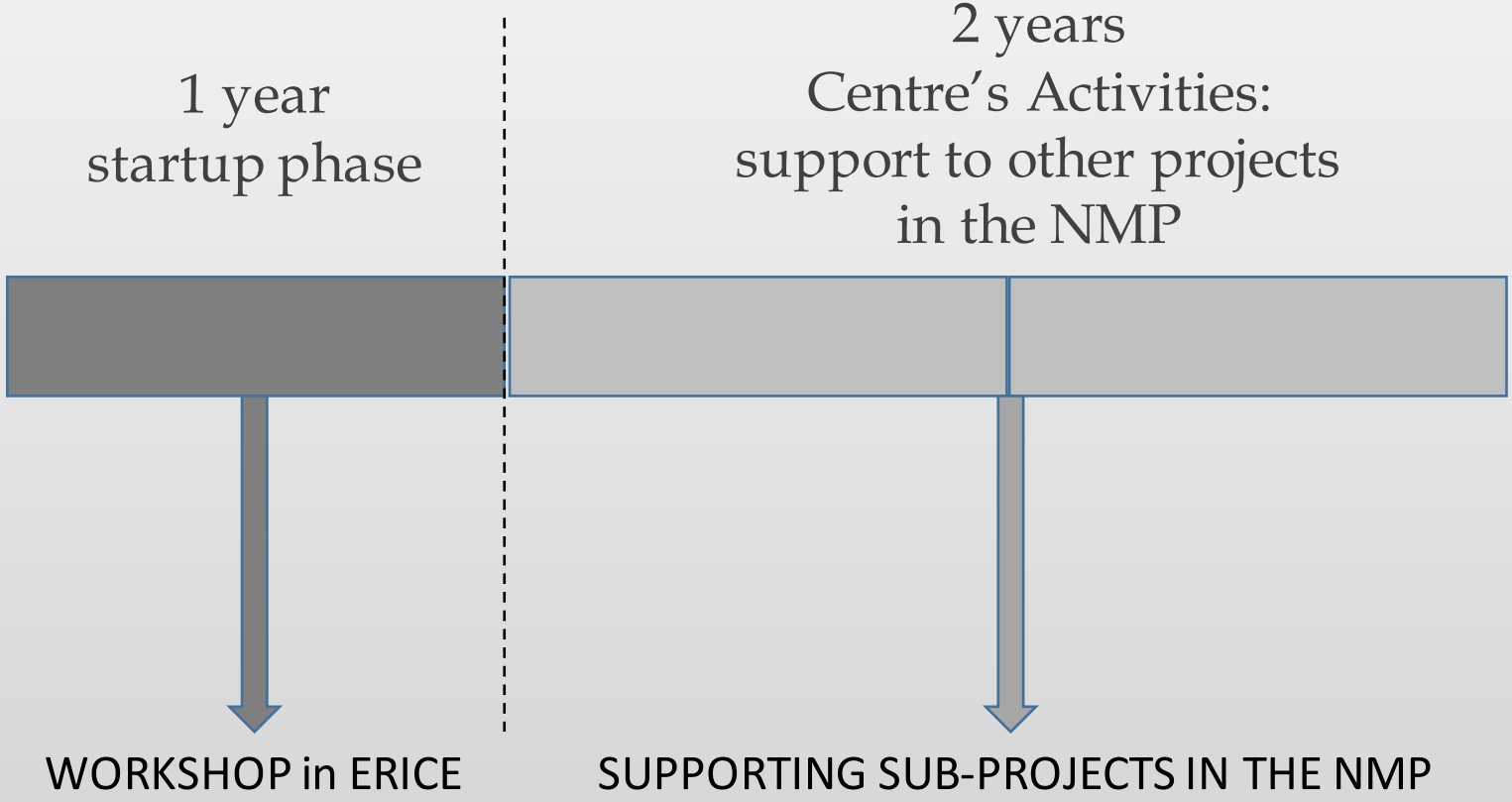
WORK PROGRAMME

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?