

# Stress testing in the context of supply chain and financial sector resilience

*Mark D. Flood, University of Maryland*

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***The Cyber-Physical-Social Infrastructure Climate Change Nexus (CPSICC)***

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# What is stress testing?

## Stress testing:

- **Is deliberate**
  - + Careful experimental design
- **Is instrumented**
  - + Input/output data
  - + Empirical analysis
- **Applies counterfactual scenarios**
  - + Exceed normal operational limits
- **Uses a realistic test subject**
  - + System itself – medical stress test
  - + Functional equivalent – automobile crash test
  - + High-fidelity model – factory-floor digital twin
  - + Low-fidelity model – banking system simulation ← **OPEN SYSTEMS**



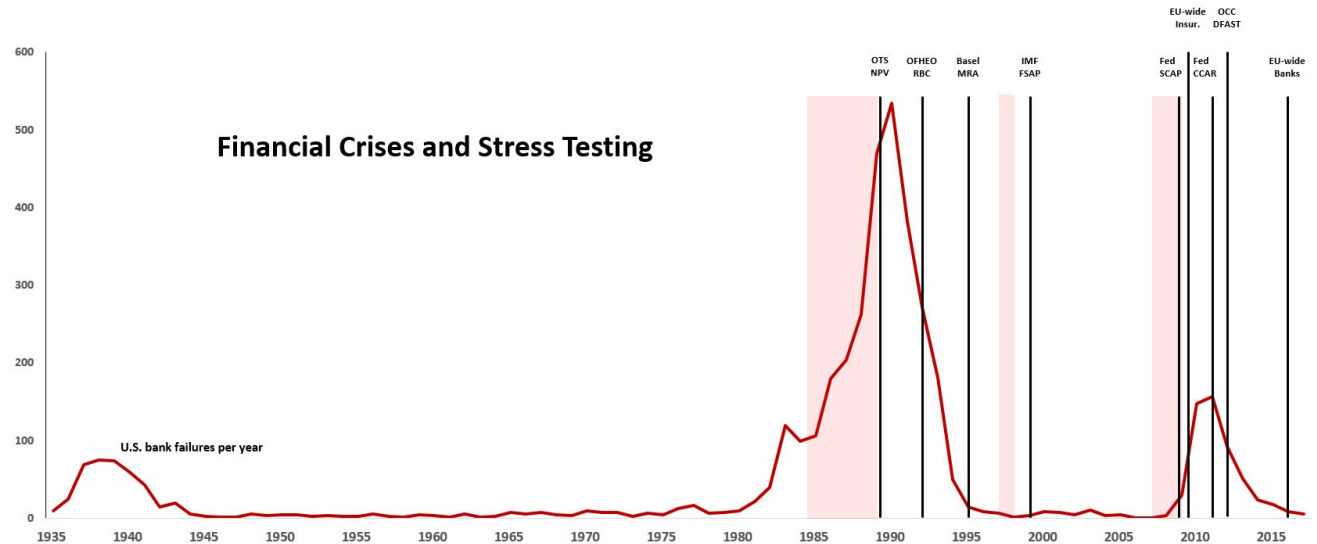
# Stress testing as a response to crisis

## Key attributes of economic systems

- Complexity
- Uncertainty
- Dynamism
- Endogeneity

## Implications

- Behavioral feedback
- Nonlinear response
- Emergent phenomena
- Punctuated equilibria



## Financial crises Granger-cause stress-testing programs:

- **1980s S&L Crisis**  
⇒ OTS NPV, OFHEO RBC, Basel MRA
- **1997 Asian Financial Crisis**  
⇒ IMF / World Bank FSAP
- **2007-09 Financial Crisis**  
⇒ Fed SCAP, Fed CCAR, OCC DFAST, EIOPA ST, EBA ST

# Forward stress testing

**Forward stress test** (notation of McNeil and Smith, 2012)

$$\mathbf{x}_{LSLE} \equiv \arg \min \{g(\mathbf{x}) : \mathbf{x} \in S\} \text{ for } S \subset \mathbb{R}^d$$

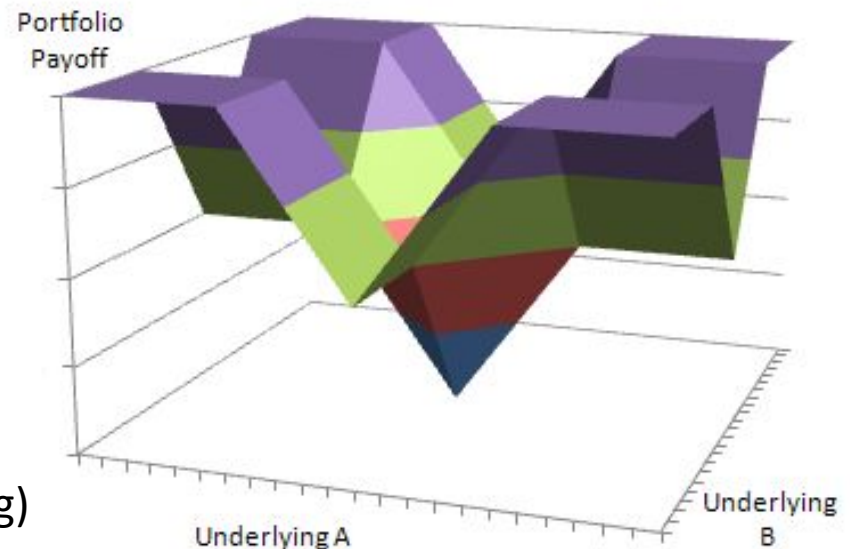
where *LSLE* = least solvent likely event (i.e., among  $\mathbf{x} \in S$ )

**CCAR and DFAST use three “likely events” (plausible scenarios):**

- Baseline
- Adverse
- Severely adverse

**Is three enough?**

- Non-monotonicity of payoffs
- Anisotropy of payoffs
- Model risk
- Data limitations
- Strategic behavior (e.g., window dressing)



# Reverse stress testing

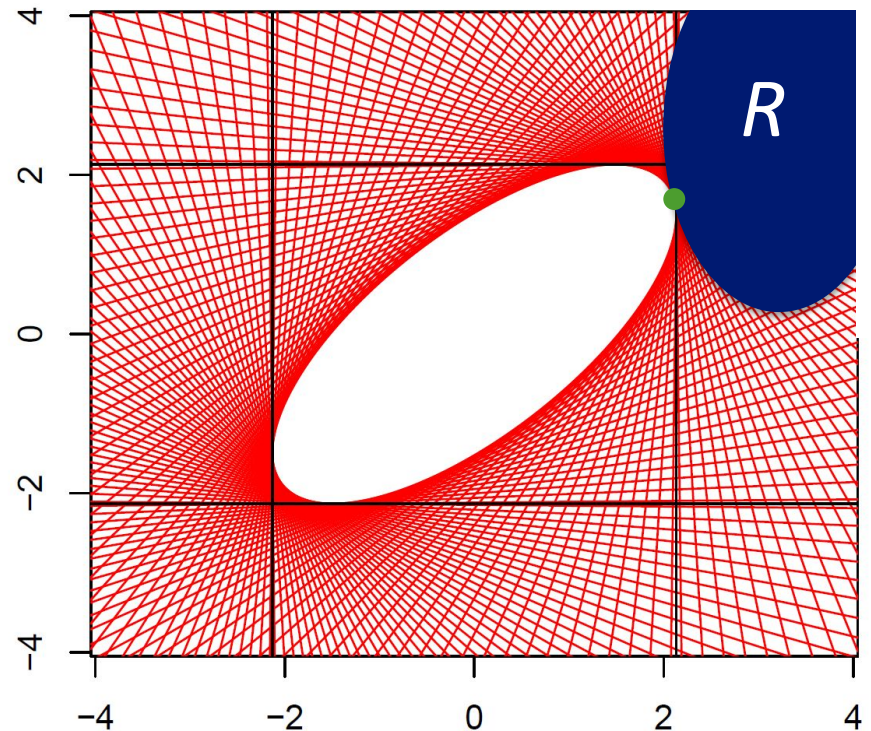
**Reverse stress test** (McNeil and Smith, 2012, again)

$$\mathbf{x}_{MLRE} \equiv \arg \max \{ \text{depth}(\mathbf{x}) : \mathbf{x} \in R \} \text{ for } R \subset \mathbb{R}^d$$

where *MLRE* = most likely ruin event (i.e., among  $\mathbf{x} \in R$ )

**Identify the set of ruin events,  $R$**

- **Pick the most likely  $\mathbf{x} \in R$**
- **Payoff surface involved directly**
- **Idiosyncratic scenarios**
  - Helps reveal cross-sectional exposure concentrations
  - Challenge for public disclosure and accountability



# Forward stress testing in practice

## Structure

- Simplest version is a model's immediate measured response to a point impulse
  - Extensions to multiperiod response, feedback effects, etc.
- Scenario design is hard
  - Severe yet plausible standard
- Data engineering is hard

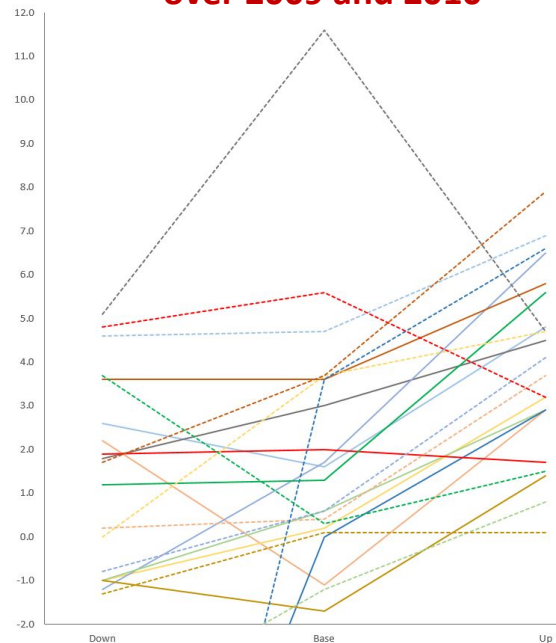
## A simple example

- 12 Home Loan Banks
  - 2009 and 2010
- Interest rate shocks
  - +200 and -200bp
- Banks' internal models
  - Full portfolio details
- Bank-level response
  - Duration of equity,  $D_e$

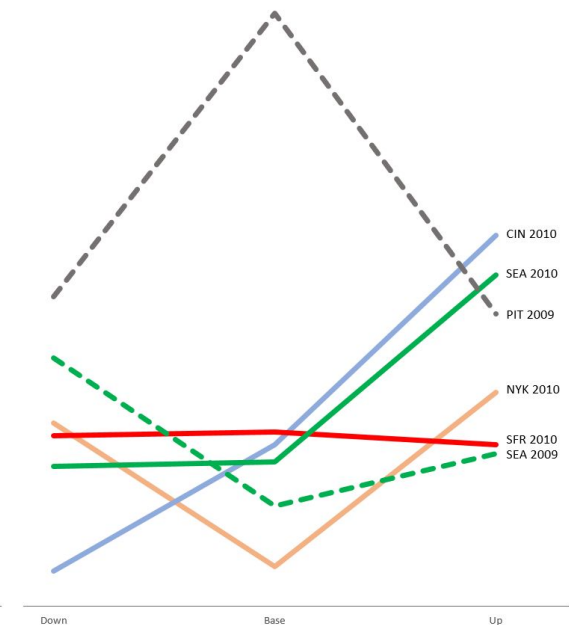
## Diverse responses

- Mostly upward sloping
  - Except ...

**$D_e$  responses for 12 FHLBanks over 2009 and 2010**



**Subset exhibiting the diversity of response surfaces**

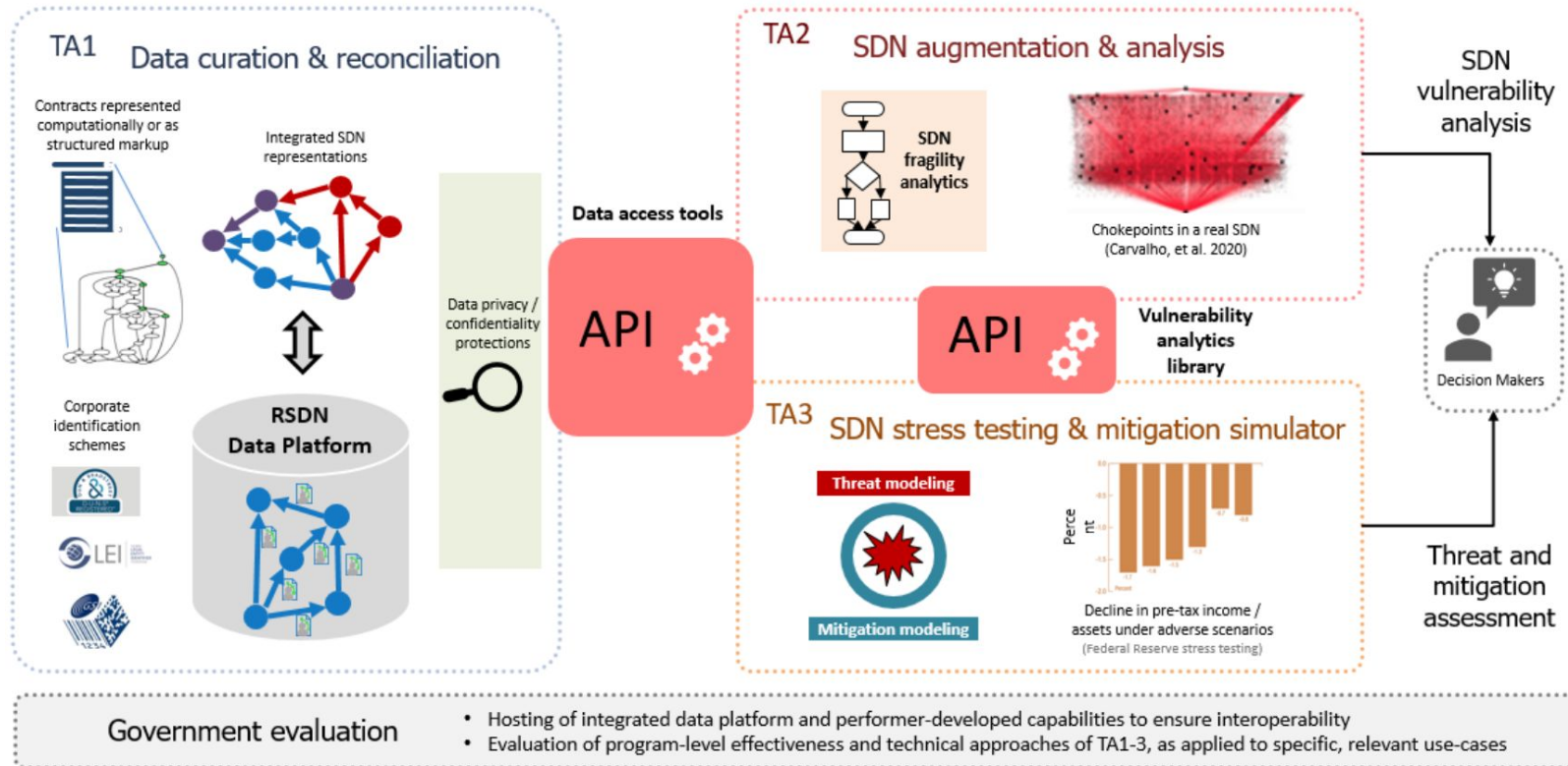




# High-level architecture

## DARPA's Resilient Supply-and-Demand Networks (RSDN) program

- Stress-testing critical procurement (not logistical) networks



### Three technical areas for implementation:

- Data curation and reconciliation
- Supply-and-demand network (SDN) augmentation and analysis
- SDN stress testing and mitigation simulator

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**Thanks!**

***Questions?***