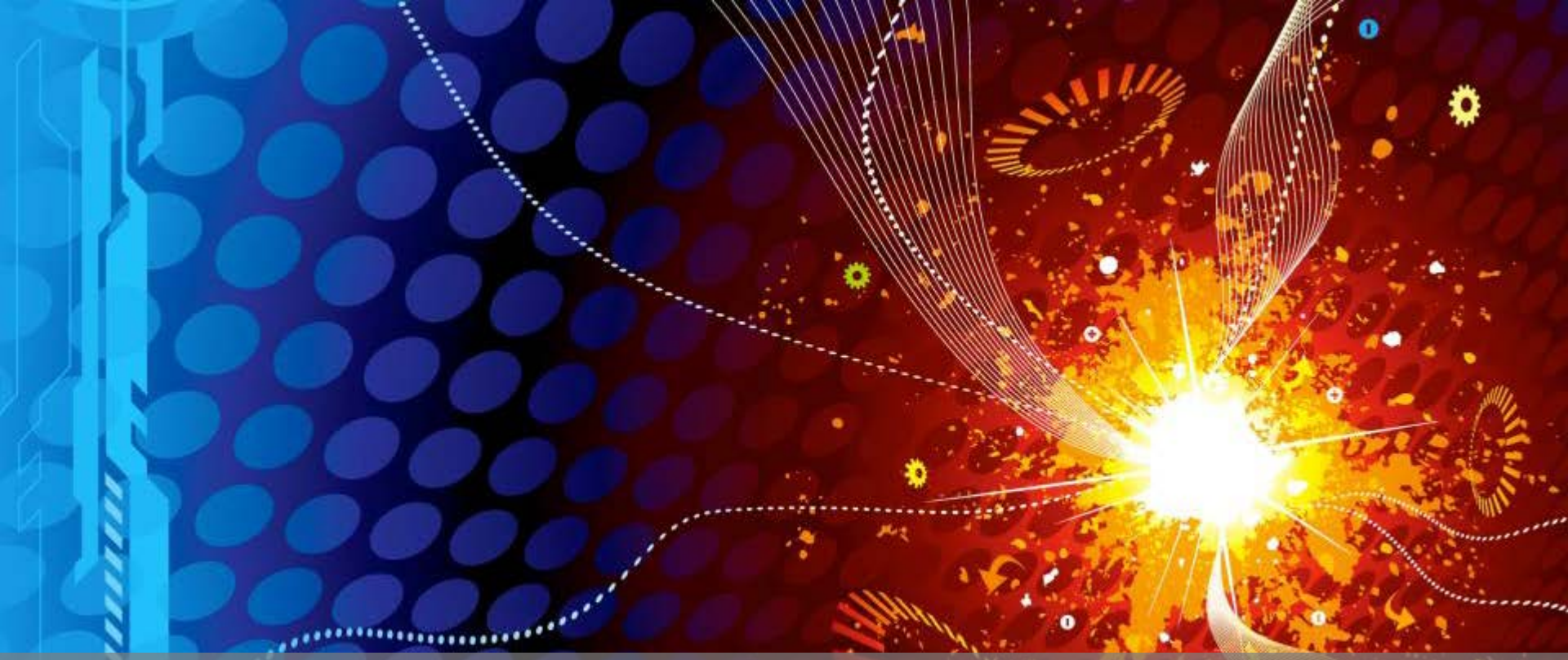


Centre for Risk Studies Research Showcase 13 January 2015

Session 1: Cambridge Risk Framework

Cambridge Risk Framework - Developments and Objectives

Centre for Risk Studies

UNIVERSITY OF CAMBRIDGE Judge Business School

Simon Ruffle

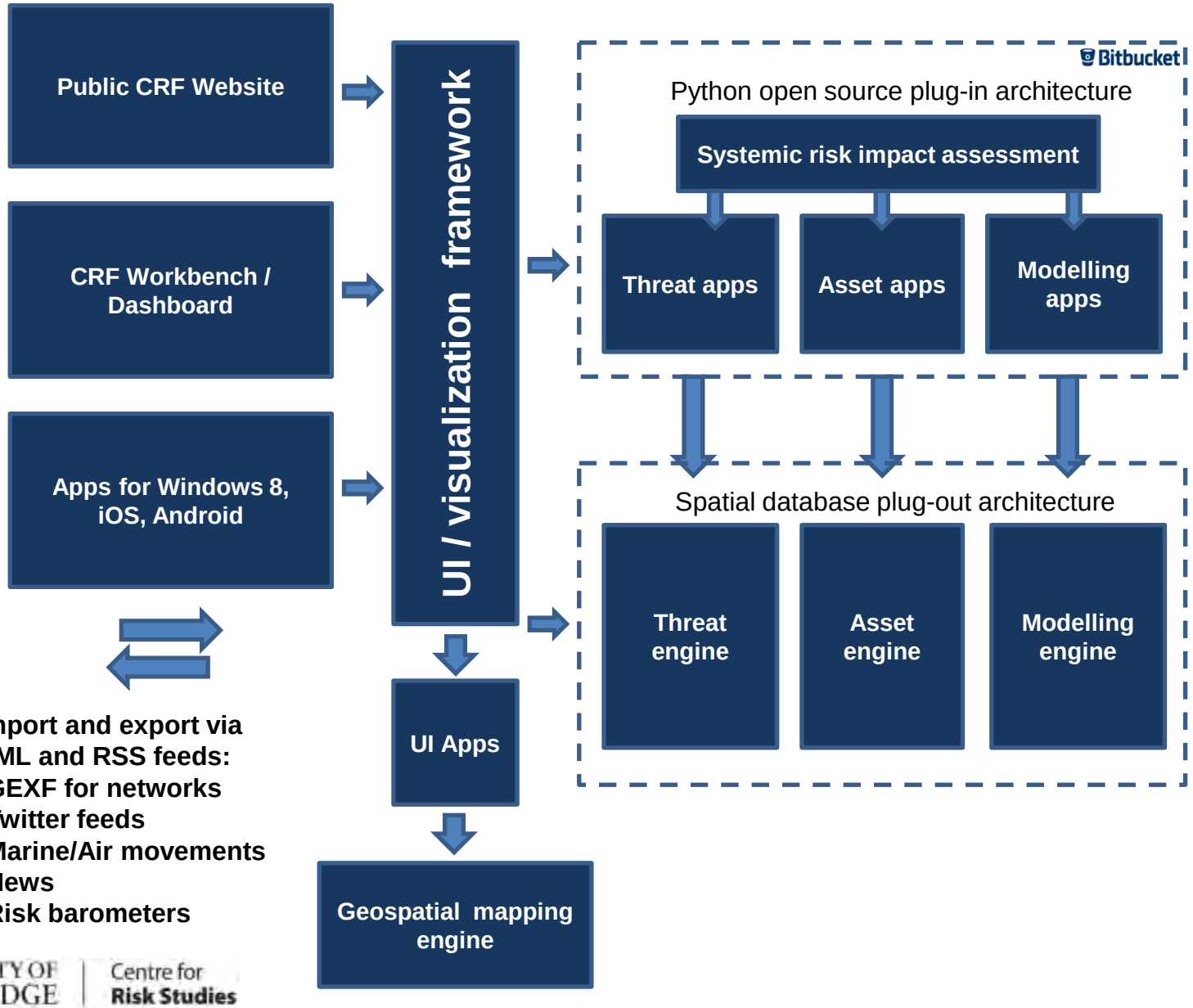
Director of Technology Research and Innovation

Centre for Risk Studies

Cambridge Risk Framework

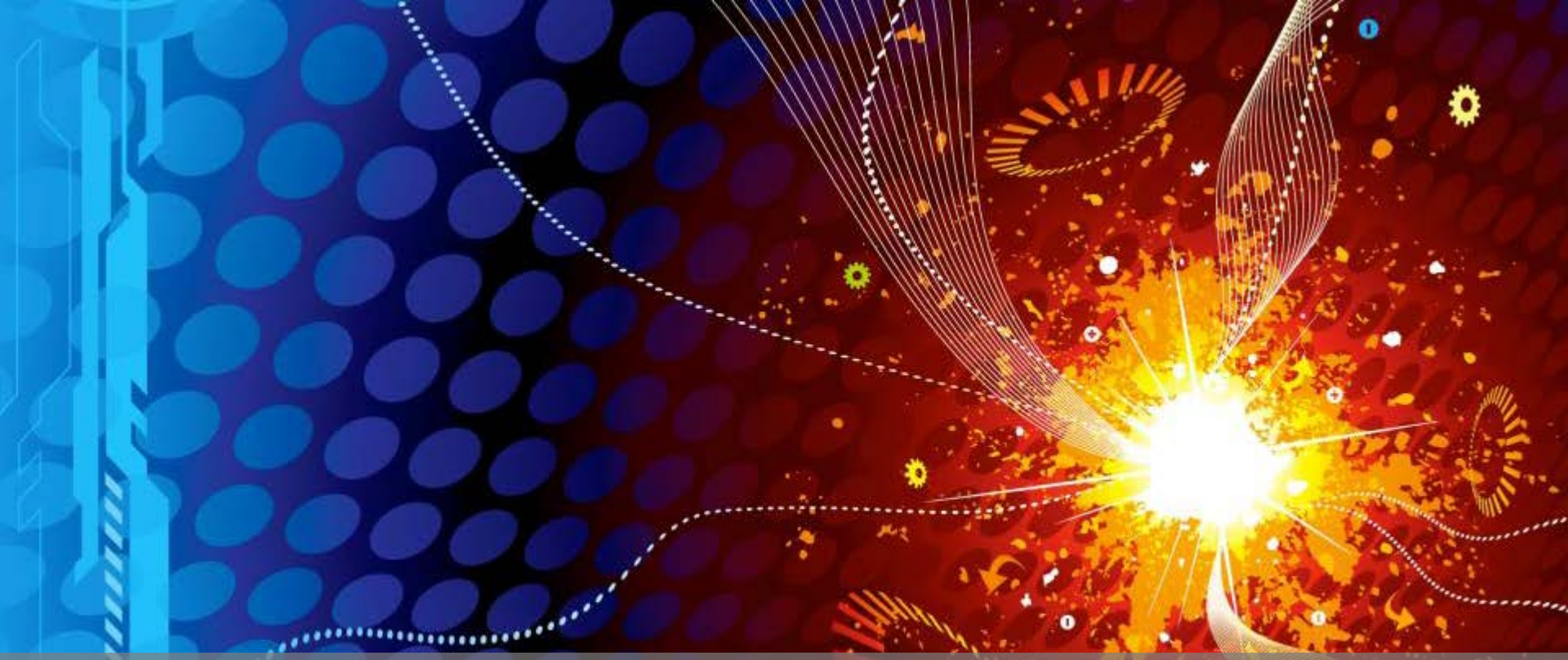
- A platform for the Centre's research
- A central data repository for the Centre
- Relational database with geospatial extensions
- Core concepts like Threat Taxonomy built in
- Data gathering programme
- Software toolkit for model development
- Mapping, network and graph drawing support tools
- Sharable, web enabled, web control panel

Cambridge Risk Framework



Import and export via XML and RSS feeds:

- **GEXF for networks**
- **Twitter feeds**
- **Marine/Air movements**
- **News**
- **Risk barometers**



Centre for Risk Studies Research Showcase 13 January 2015

Session 1: Cambridge Risk Framework

Cities at Risk / Risk Atlas

Centre for Risk Studies

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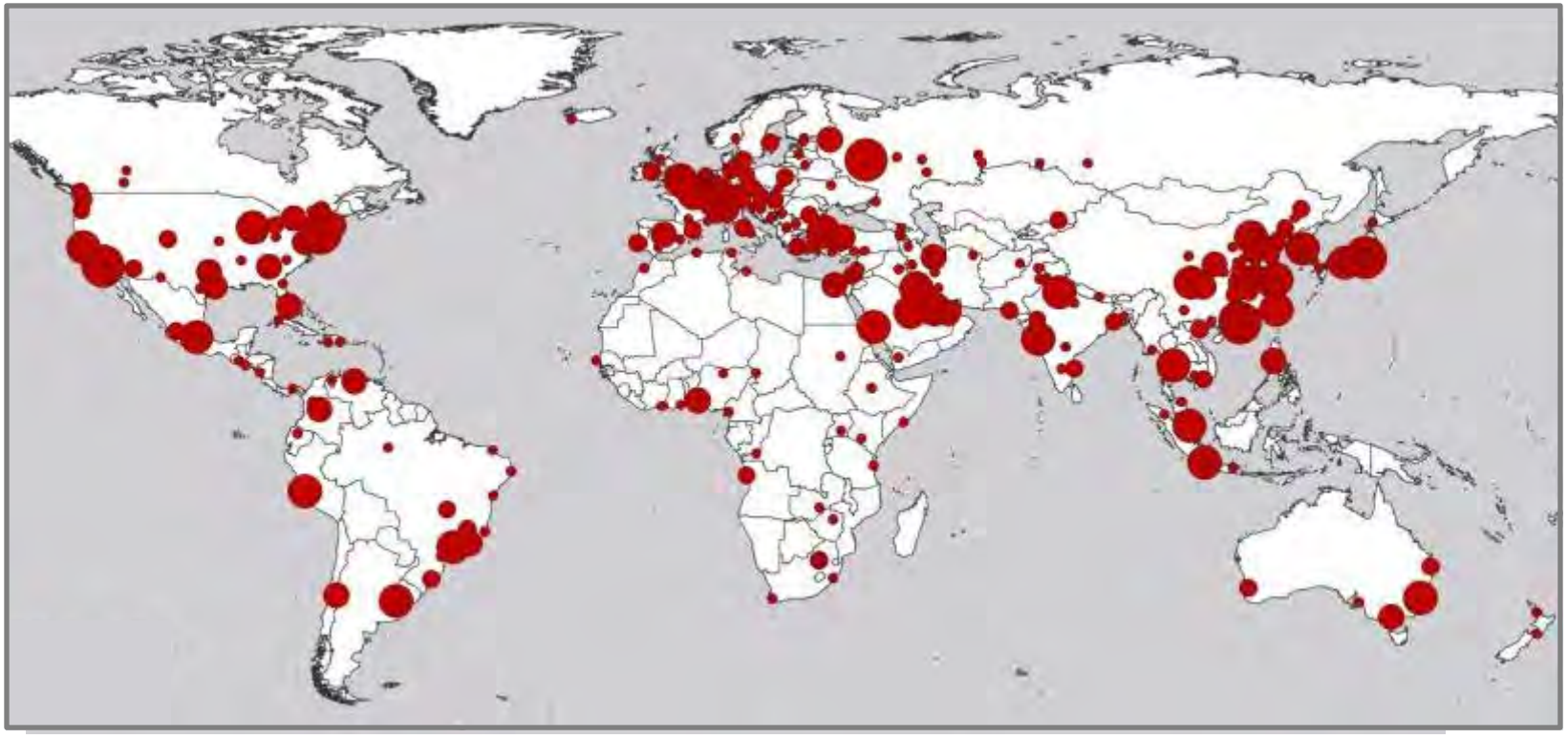
Simon Ruffle

Director of Technology Research and Innovation

Centre for Risk Studies

Cities at Risk



We picked the 'A List' of the world's cities for this analysis, which:

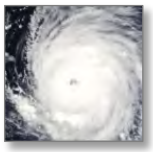
- Are responsible for **half** of the World's GDP today
- Will be responsible for **two-thirds** of the World's GDP in **2025**
- Are the largest cities in the 50 largest economies in the world
  - Top 25 cities in US (#1 economy) and top 32 cities in China (#2 economy)
  - Between 5 and 12 top cities for each of the rest of the top 17 economies
- Include all cities over 3m population in the world
- Consist of half of the world's capital cities

1

Natural Catastrophe & Climate

Earthquake

Volcanic Eruption



Windstorm
- Tropical
- Temperate

Flood

Tsunami

Drought

Freeze

Heatwave

2

Financial, Trade & Business

Market Crash

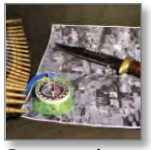
Sovereign Default

Oil Price Shock

3

Politics, Crime & Security

Interstate War



Separatism

Terrorism

Social Unrest

4

Technology & Space

Power Outage

Cyber Catastrophe

Solar Storm

Nuclear Meltdown

5

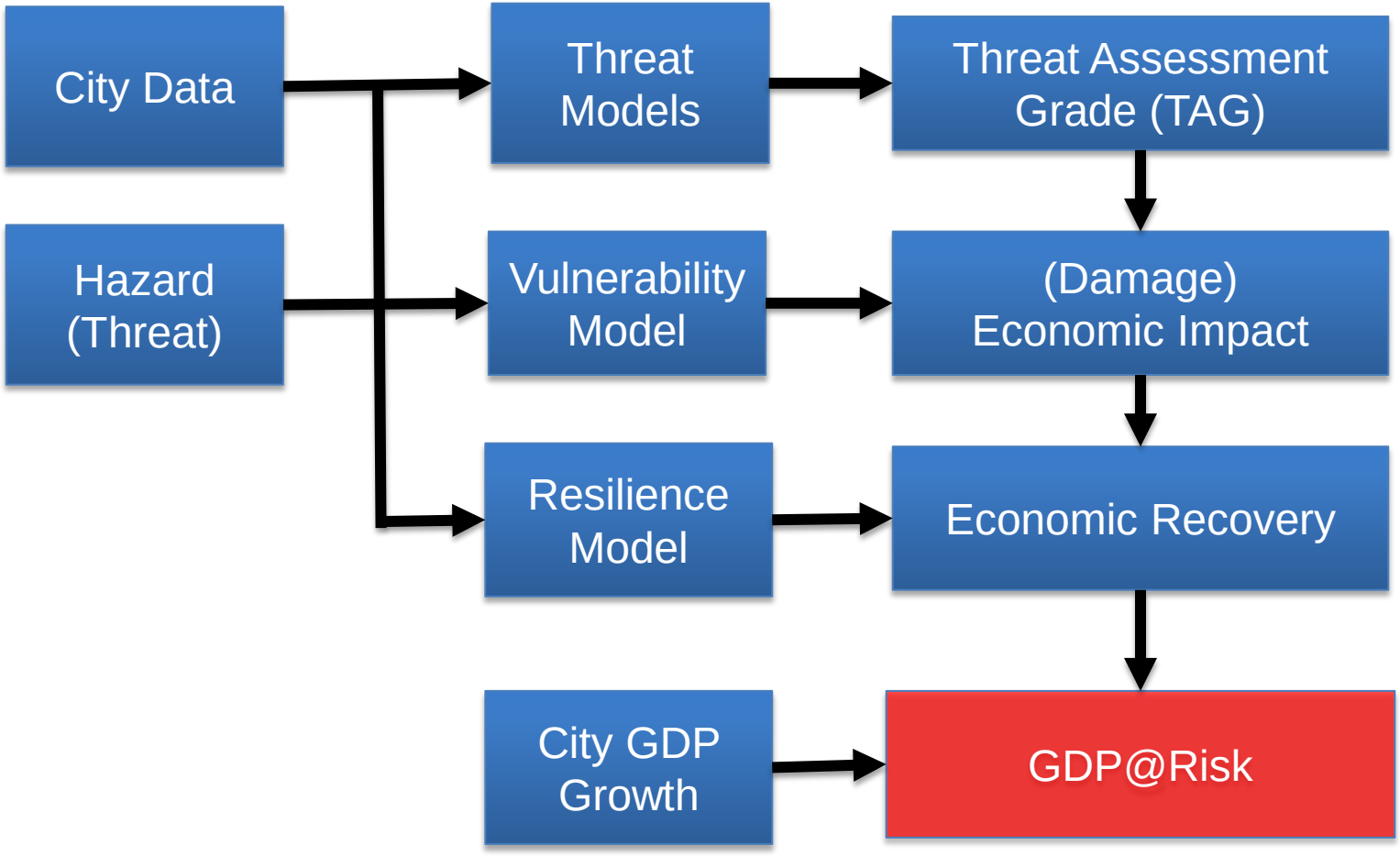
Health & Environmental

Human Epidemic

Plant Epidemic Crop Failure

23 Threats

GDP@Risk Estimation Process



A Frequency and Severity Model for Each Threat

- Identification of the authoritative science about each threat
  - Key data repository
- Geographical mapping of frequency and severity
  - Threat Assessment Grading for 300 cities
- Definition of a magnitude scale of occurrence
  - How big and how often might we expect this threat over the next 10 years?
- Quantification of the frequency and severity of each threat globally
  - Regional frequency and severity in many cases
- Definition of three ‘characteristic scenarios’ of each threat
- Definition of intensity scale for experiencing the threat scenarios at a location (city)
- Quantification of the economic impact of each characteristic scenario on a typical city
  - Incorporating physical vulnerability and social and economic resilience of the city
  - Output in terms of ‘GDP@Risk’ –a standard metric to compare different threats

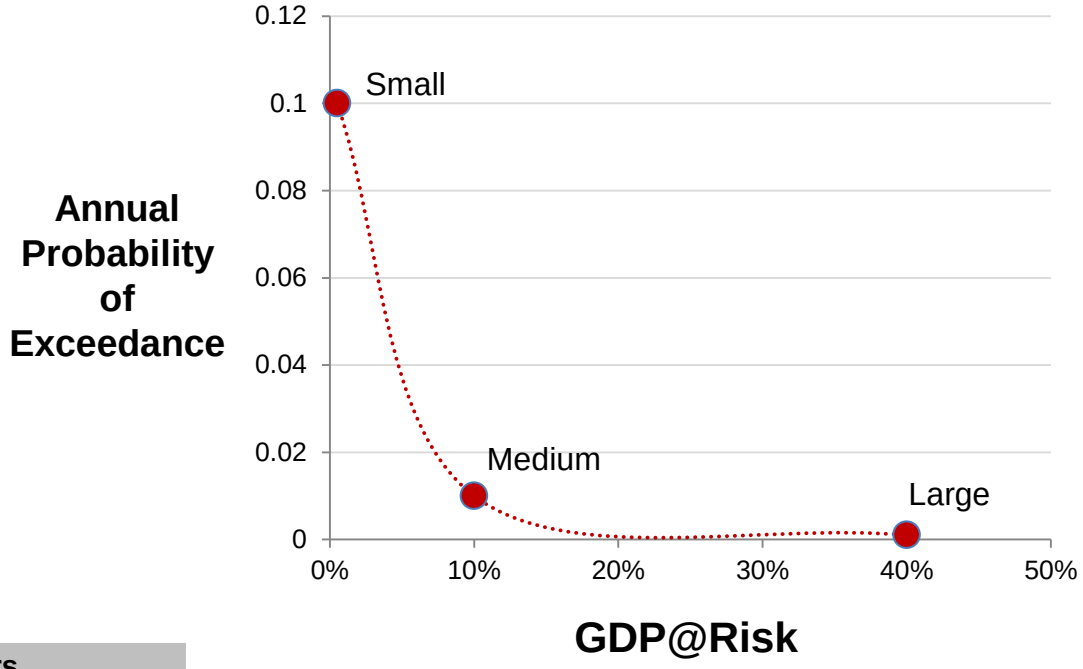
The Maths: Simplified Exceedance Probability

3

Nature

For one threat type, e.g. Nature, in one city, e.g. Mexico City

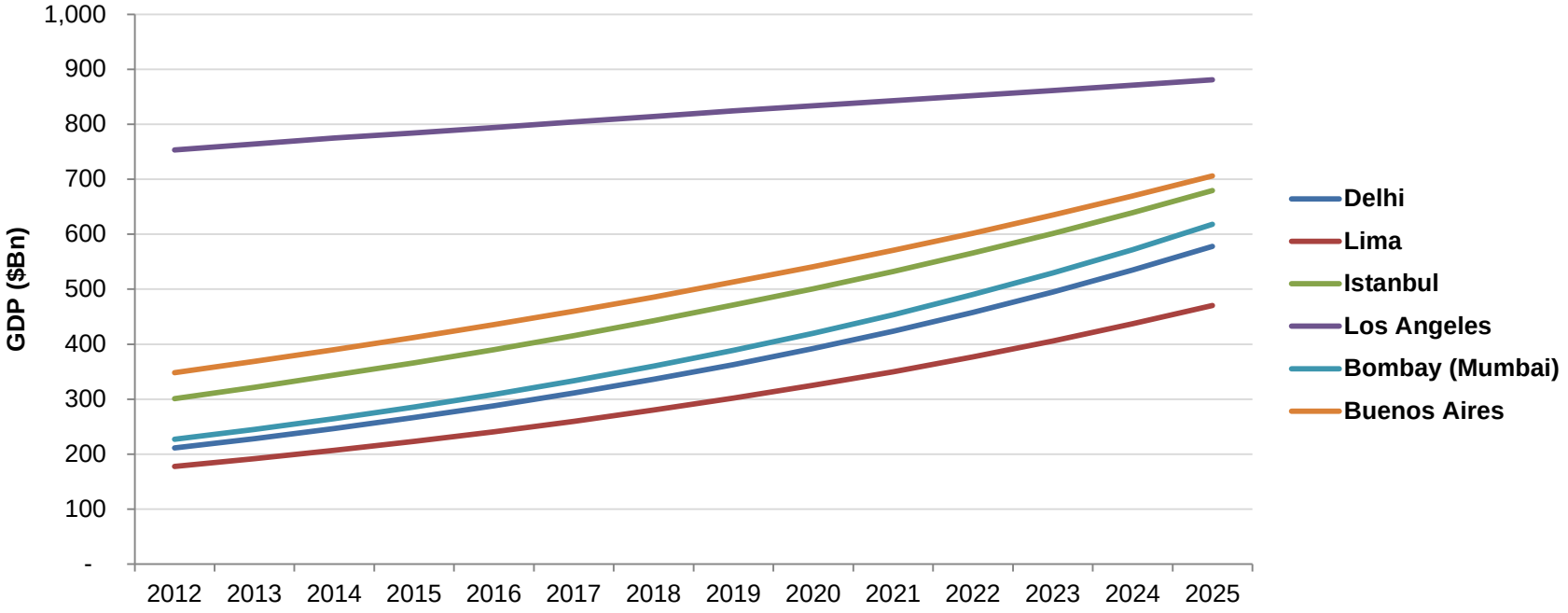
	GDP@Risk	Annual Prob of Exceedance
Small	0.50%	0.1
Medium	10%	0.01
Large	40%	0.001



	Prob of N events in 10 years					
	0 events	1 event	2 events	3 events	GDP@Risk	Prob Wtd
Small	0.349	0.387	0.194	0.057	0.50%	0.32%
Medium	0.904	0.096	0.010	-	10%	1.05%
Large	0.990	0.010	-	-	40%	0.40%
Expected GDP@Risk from Threat Type X to Mexico City 2014-2025						**1.77%**

- All occurrence is independent and random
- No compounding of effects

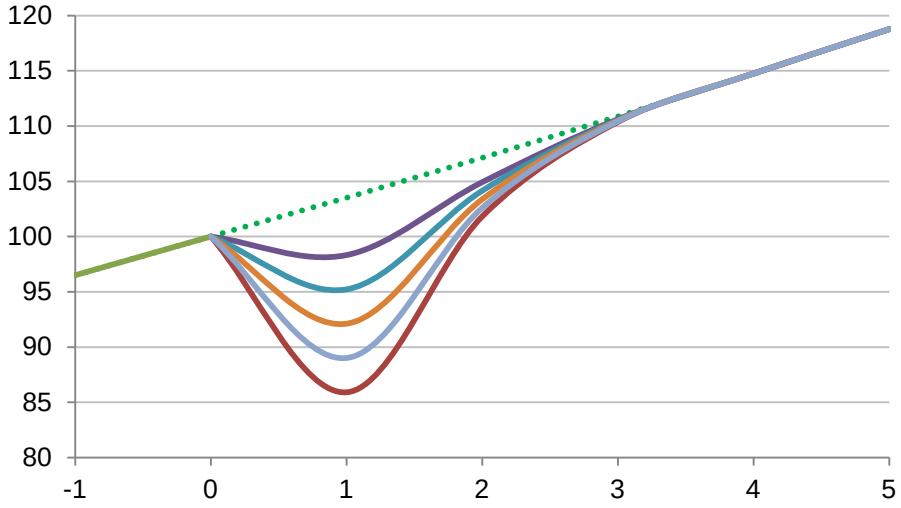
GDP Projections



- GDP projections for each year to 2025 have been derived for each of the 300 cities
- These draw on studies from McKinsey, Brookings Institute and others
- Projections take account of trends in GDP and future demographic change.

Vulnerability of the City influences Shock Severity

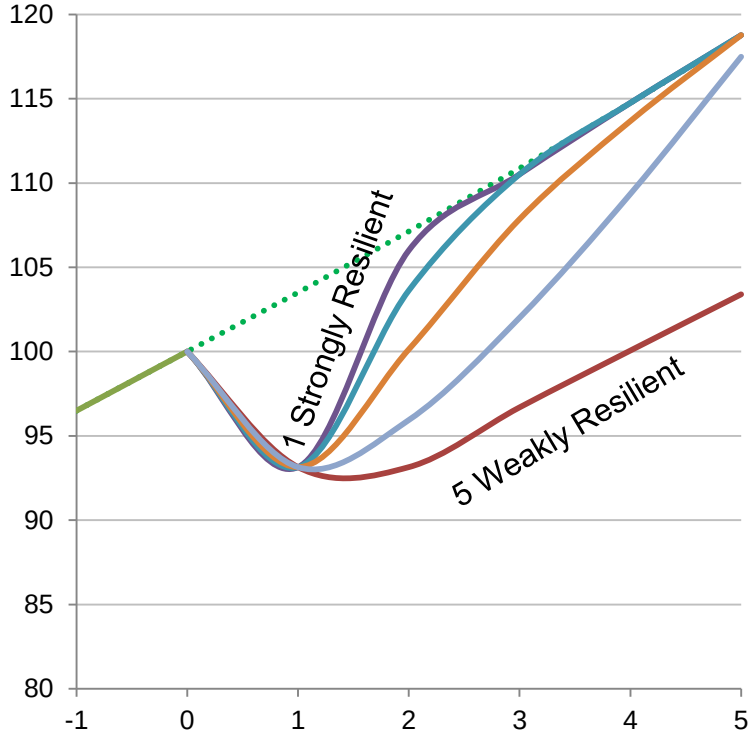
	Small	Medium	Large
1 Very Strong	97.0%	95.0%	80.0%
2 Strong	95.0%	85.0%	70.0%
3 Moderate	90.0%	75.0%	60.0%
4 Weak	80.0%	68.0%	50.0%
5 Very Weak	75.0%	50.0%	40.0%



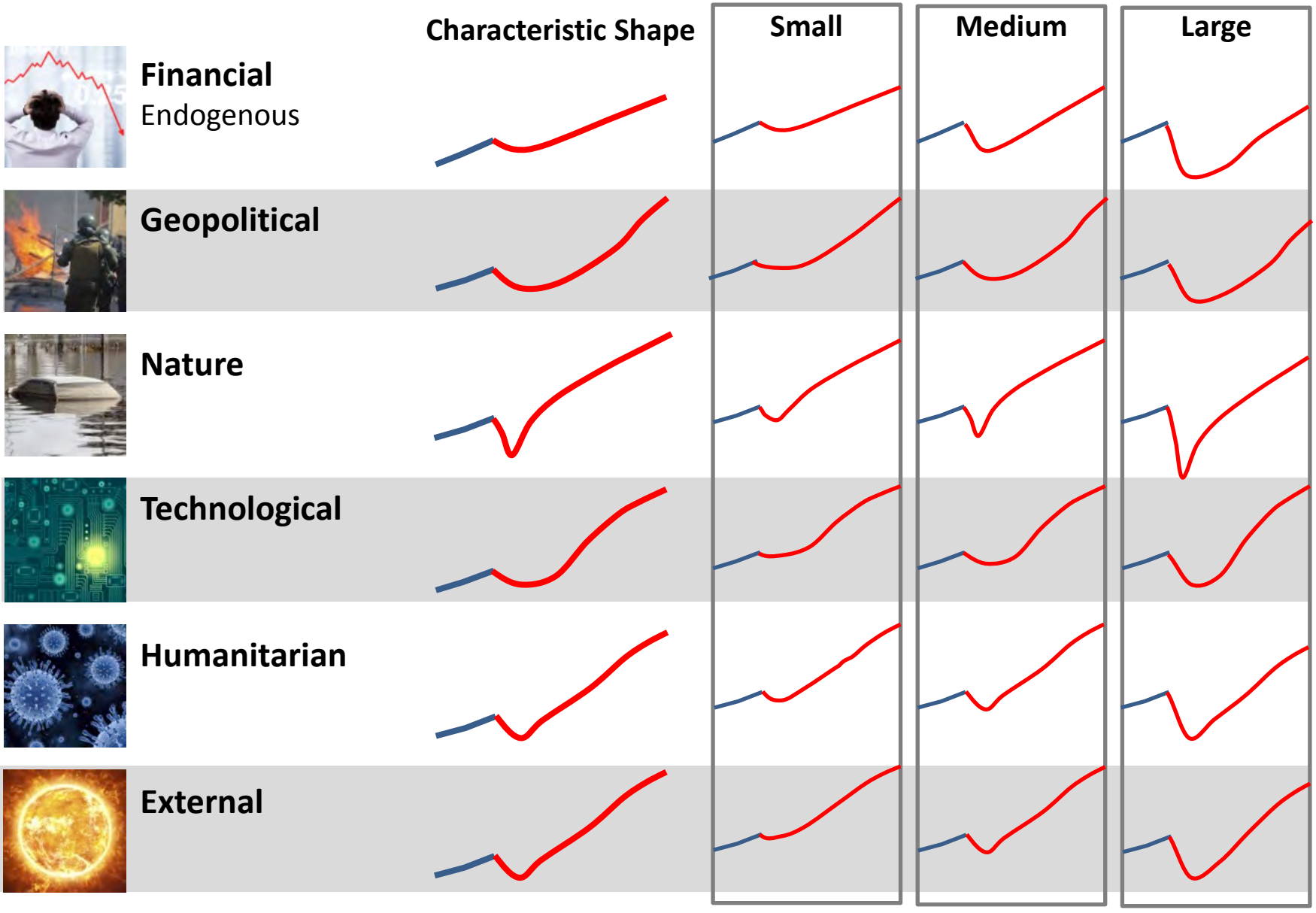
- Physical Vulnerability includes assessment of the quality of buildings and compliance to construction codes, such as seismic
- Flood Vulnerability considers water damage loss by economic sector
- Cyber Vulnerability considers the reliance on IT and its criticality for the city's economic output
- Financial Vulnerability considers connectivity and impact from a financial crisis
- Pandemic Vulnerability includes healthcare index assessment by World Health Organization

Resilience: Recovery Speed

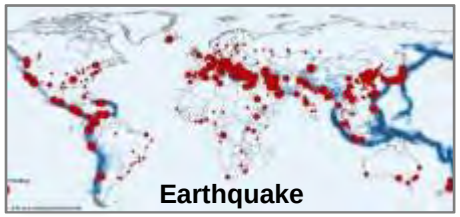
- The speed of recovery of the city is influenced by its social and economic resilience
- We have developed a Resilience classification (1-5) for cities based on four factors (adaptation of an accepted technique ND-GAIN)
  - Governance; Social coherence; Economic strength; Infrastructure
- Resilience' of the city determines how long the recovery process takes
- Recovery is calibrated from precedent studies of economic recovery after disaster

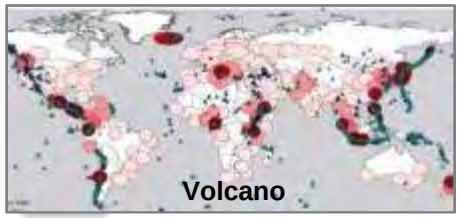


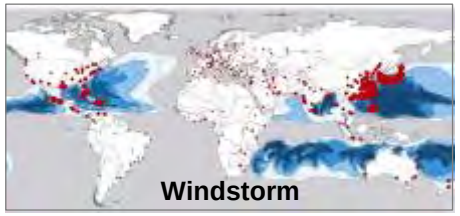
Future Crises and their Characteristics

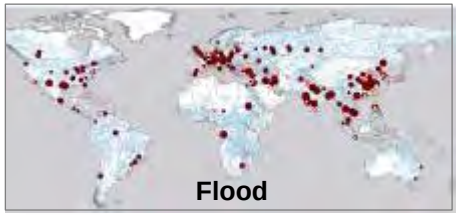


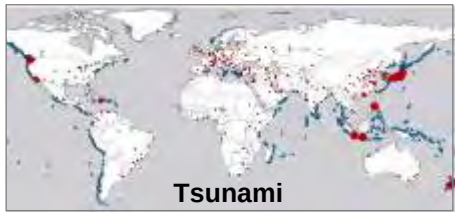
Eighteen 'event templates'

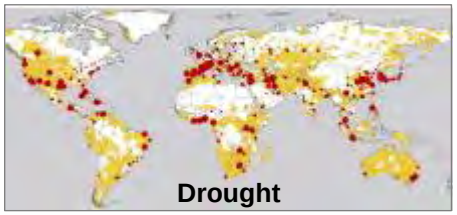


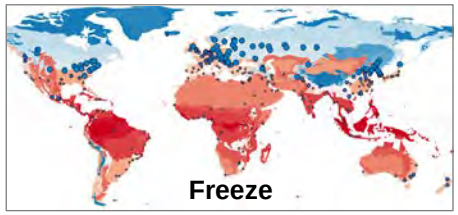


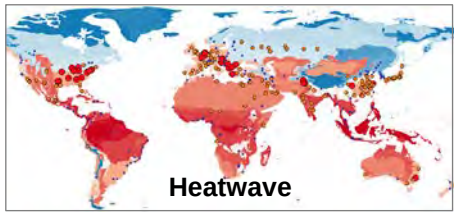


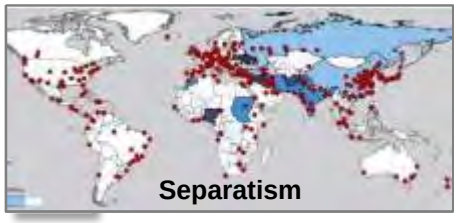


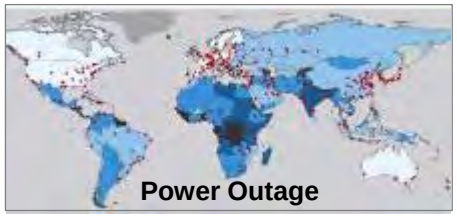


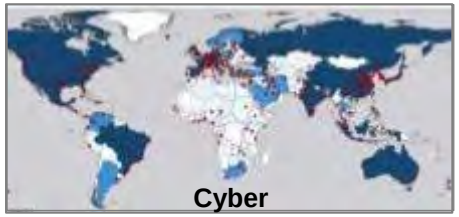


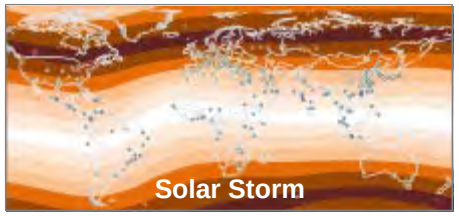


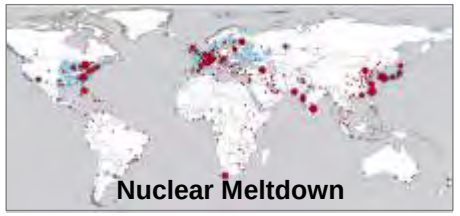












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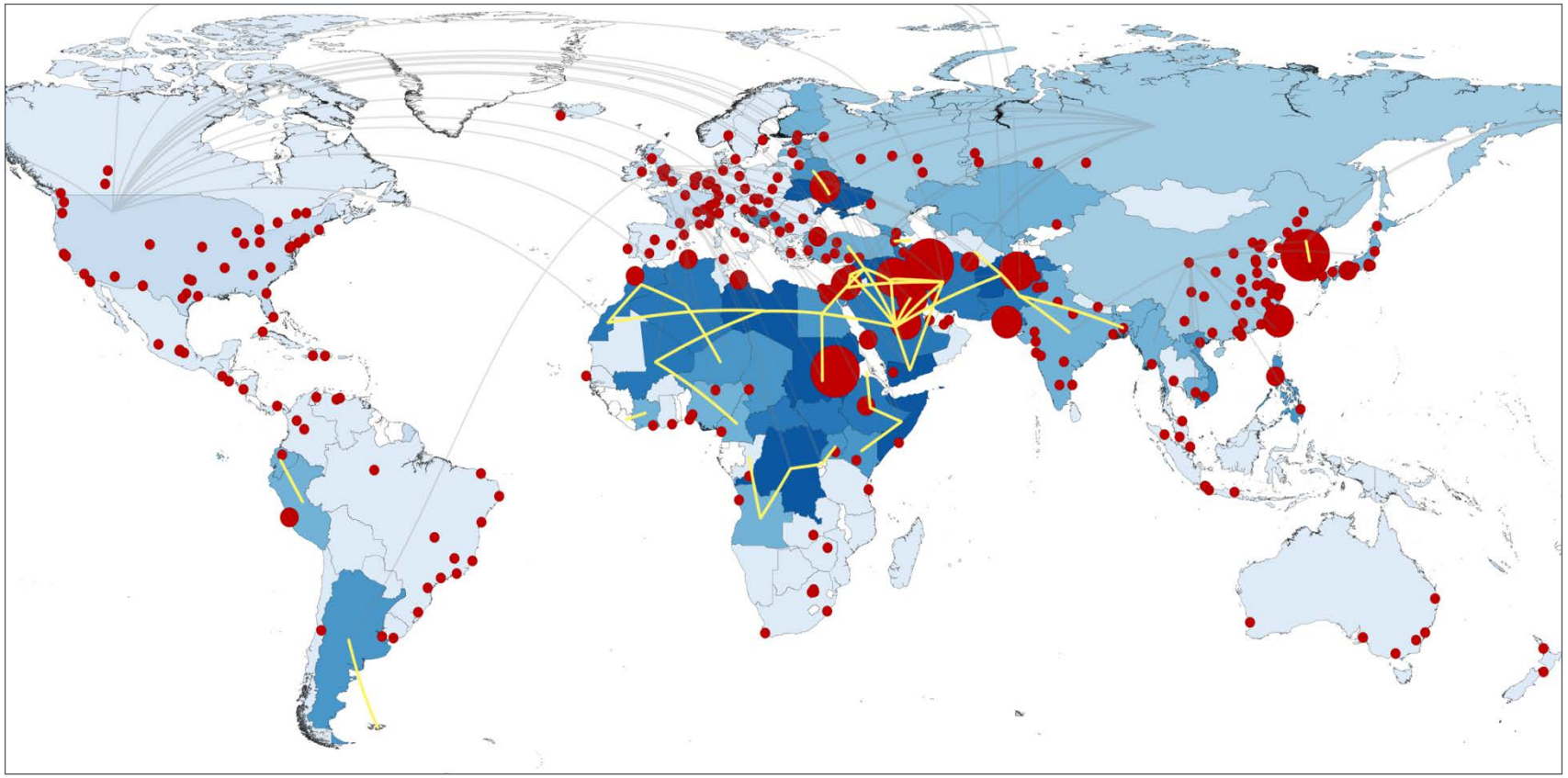
Cambridge Risk Atlas

Interstate War



City GDP@Risk (US$ Bn)

- 0.00 - 8.23
- 8.23 - 16.4
- 16.4 - 24.6
- 24.6 - 32.9
- 32.9 - 41.1

Interstate War Threat

- A Very High Threat of Interstate Conflict
- B High Threat of Interstate Conflict
- C Moderate Threat of Interstate Conflict
- D Low Threat of Interstate Conflict
- E Major Power with Some Threat of Conflict
- F Major Power with Very Low Threat of Conflict
- G Conflict is Possible but No Scenarios Identified

Lines of Conflict

- Conflict with world superpower state
- Conflict among other states

Wars have had major impacts on economic growth throughout history. Wars are less common since 1945 – 'the Long Peace' – than in previous eras, but still pose major threats. Using analysis from Cytora Ltd. countries are graded by military power and over 100 candidate scenarios for future interstate wars are shown using an index of hostility between nations, counting acts of enmity, political friction, and history of their belligerence. Wars are likely to occur between minor military powers, major to minor, and between major powers (yellow lines). Superpowers may conduct military operations against other nations (grey lines). No conflicts occur between superpowers. Characteristic scenarios are assessed for protagonist states:

IW1 City mobilized for war, but not attacked; mobilization switches civilian commerce to military production; population gripped by fear, consumer demand drops, parts of population flees. Investor confidence is affected; Conflict lasts a year.

IW2 City suffers sporadic attack from occasional missiles or aerial bombardment, possible damage to city infrastructure from military cyber attack; City is mobilized for war; significant emigration of population from city. Investors withdraw.

IW3 City is the target of strategic bombing by enemy forces, destroying industrial and commercial output and military facilities in the city; Major emigration by population. Possible rebuilding afterwards by major injection of capital. Conflict lasts 3 years.

Top 10 Cities by GDP@Risk ($US Bn)

1	IRN	**Tehran**	41
2	SDN	**Khartoum**	35
3	KOR	**Seoul**	32
4	IRQ	**Baghdad**	29
5	ISR	**Tel Aviv**	22
6	UKR	**Kiev**	21
7	TWN	**Taipei**	20
8	SAU	**Riyadh**	18
9	PAK	**Karachi**	18
10	KWT	**Kuwait City**	17

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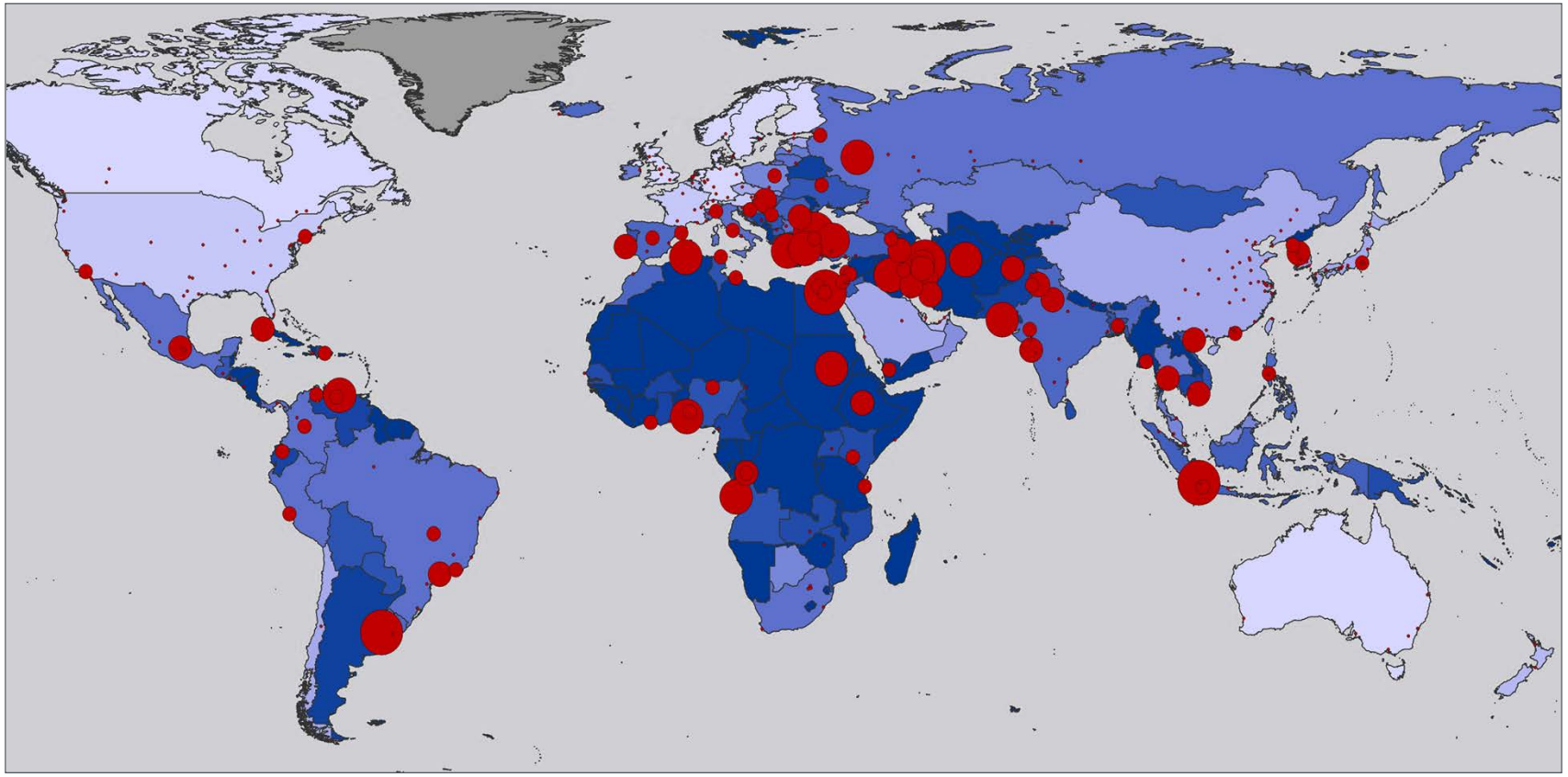
Sovereign Default



Credit Rating: Threat Assessment Grading

AAA AA+ AA AA- A+ A A- BBB+ BBB BBB- BB+ BB BB- B+ B B- CCC+ Ungraded

City - GDP@Risk ($US Bin)

0.0 - 0.4 0.4 - 1.2 1.2 - 2.3 2.3 - 4.0 4.0 - 12.4

Sovereign default, where a national government is unable to meet its financial obligations or honour its treasury bonds, results in devaluation of the national currency and the loss of foreign direct investment, which can have significant impact on the economic outputs of cities in that country. The published national credit rating of Standard and Poor's for June 2014 (pre-dating the Argentina default of July 2014) is used to assess the probability of national default, combined with an historical perspective of past defaults by countries from the post-1810 catalogue of Reinhart & Rogoff. The national assessment is applied to all cities in that country, to assess GDP loss and probability of the characteristic scenario of default:

SD1 Country defaults and reschedules its debt, devalues its currency substantially; Investors flee. National economy loses substantial foreign direct investment

Top 10 Cities by GDP@Risk ($US Bn)

1	ARG	**Buenos Aires**	12
2	TUR	**Istanbul**	10
3	IRN	**Tehran**	9
4	EGY	**Cairo**	8
5	IDN	**Jakarta**	7
6	VEN	**Caracas**	4
7	TUR	**Ankara**	3
8	ALG	**Algiers**	3
9	SDN	**Khartoum**	3
10	IRN	**Meshed**	3

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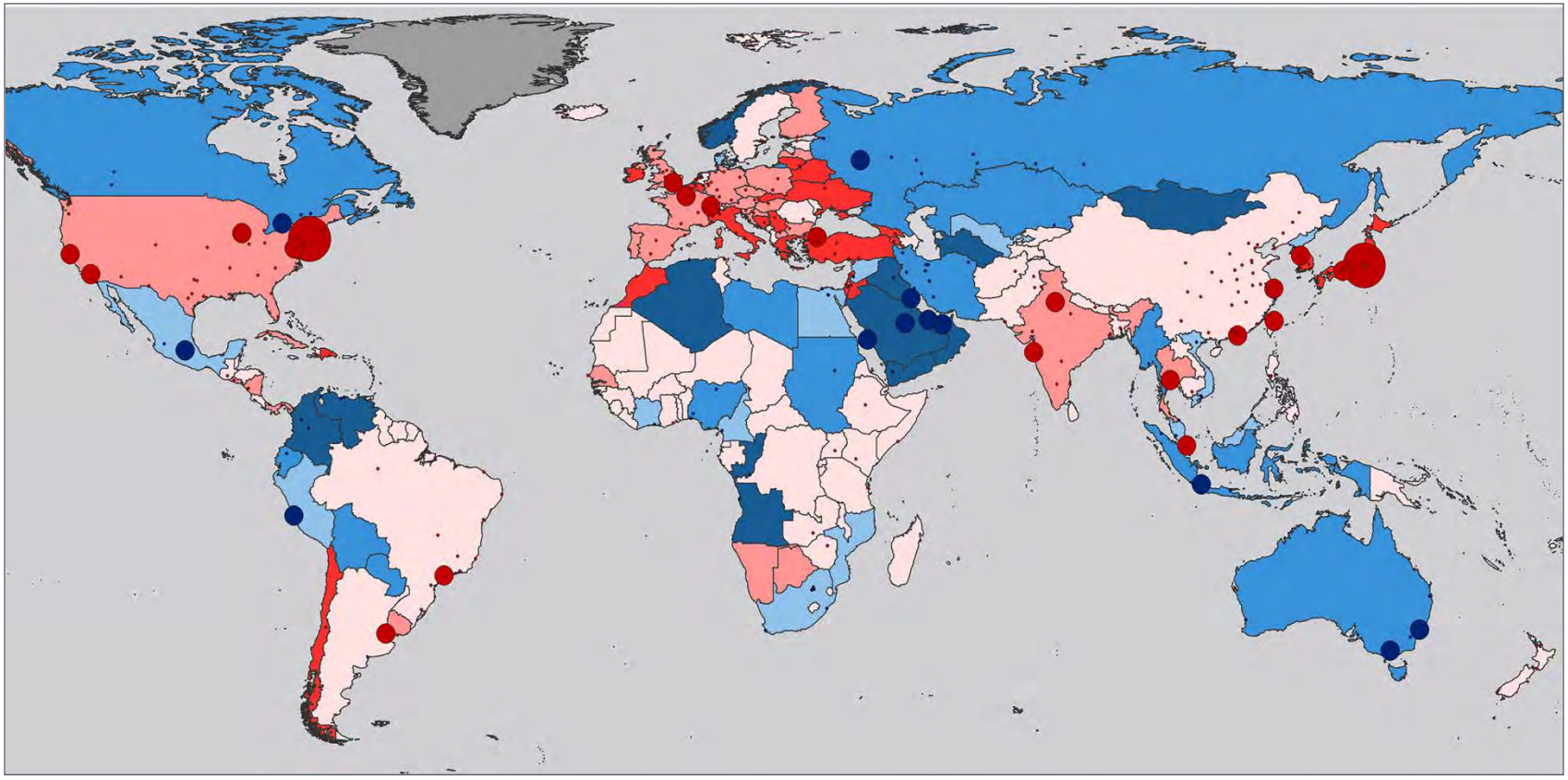
Oil Shock



City GDP@Risk (US$ Bn)

- 15.00 - 23
- 5 - 15
- 0.01 - 5
- - 0.01 - -5
- -15 - -5

Financial Crisis Threat

- A - High Vulnerability
- B - Moderate Vulnerability
- C - Some Vulnerability
- X - Exports marginally more oil than it consumes - economy would marginally
- Y - Exports significantly more oil than it consumes - economy would benefit
- Z - Exports a lot more oil than it consumes - Economy would see significant benefit
- No Data

Sudden increases in the price of key commodities are disruptive to economic prosperity, most critically the cost of energy, as represented by oil price. World Bank data on the energy intensity of each country, (i.e. the consumption of fossil fuels to produce a unit of GDP), provides insights into the sensitivity of that country's economy to an oil price shock. This is complicated by the fact that some countries are net exporters of oil, and a price increase would be beneficial to the country's balance of trade. The historical volatility of oil prices and how often past price shocks have occurred is taken as a benchmark for future likelihoods. The characteristic scenarios for oil price shocks gives impacts on the GDP of each city:

OP1 Sudden increase in oil price by 10%

OP2 Sudden increase in oil price by 25% (similar to Oil Price crisis of 1974)

OP3 Sudden increase in oil price by 50%

Top 10 Cities by GDP@Risk ($US Bn)

1	JPN	**Tokyo**	21
2	USA	**New York**	15
3	KOR	**Seoul**	12
4	USA	**Los Angeles**	12
5	FRA	**Paris**	10
6	SGP	**Singapore**	9
7	TUR	**Istanbul**	9
8	GBR	**London**	8
9	JPN	**Osaka**	8
10	TWN	**Taipei**	7

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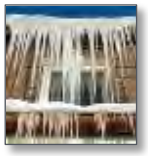
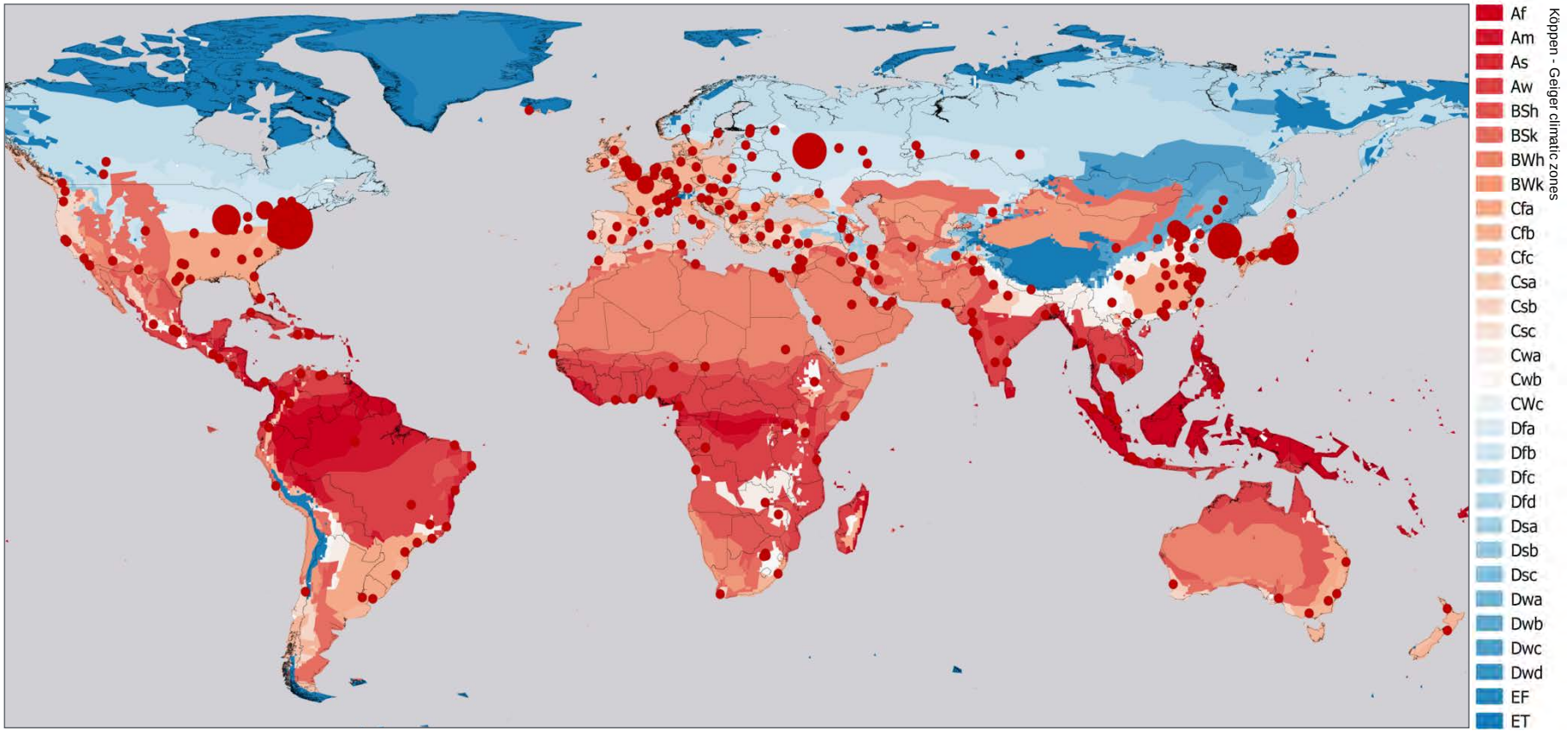


Freeze



City GDP@Risk (US$ Bn)

- 0.00 - 0.46
- 0.46 - 0.93
- 0.93 - 1.40
- 1.40 - 1.87
- 1.87 - 2.34

Extreme temperature events are most disruptive in climatic regions where they occur only rarely and cities are not well prepared, Extreme freeze events in temperate climatic regions disrupt transport, close airports and ports, and damage infrastructure. Temperature records and historical weather accounts, including those compiled by World Health Organization, EM-DAT, and US Centres for Disease Control, provide analysis of freeze threat. Cities are shown here on Köppen–Geiger climate zones. Duration and severity provide degree-day severity metrics for freeze events. Cities are analyzed by the likelihood of experiencing characteristic scenarios and their vulnerability to them:

FR1 Freeze of up to 5 deg below 0 deg Celcius for 3 weeks (-20-100 Degree-days) with some snow and ice, moderate winds

FR2 Freeze of up to 10 deg below 0 deg Celcius for 8 weeks, combined with deep snow and high winds

FR3 Freeze of up to 20 degrees below 0 deg Celcius for 12 weeks, combined with heavy snow and severe ice loads periodically

Top 10 Cities by GDP@Risk ($US Bn)

1	USA	**New York**	2
2	RUS	**Moscow**	1
3	KOR	**Seoul**	1
4	JPN	**Tokyo**	1
5	USA	**Chicago**	1
6	CHN	**Beijing**	.8
7	USA	**Washington DC**	.7
8	FRA	**Paris**	.6
9	CAN	**Toronto**	.5
10	GBR	**London**	.5

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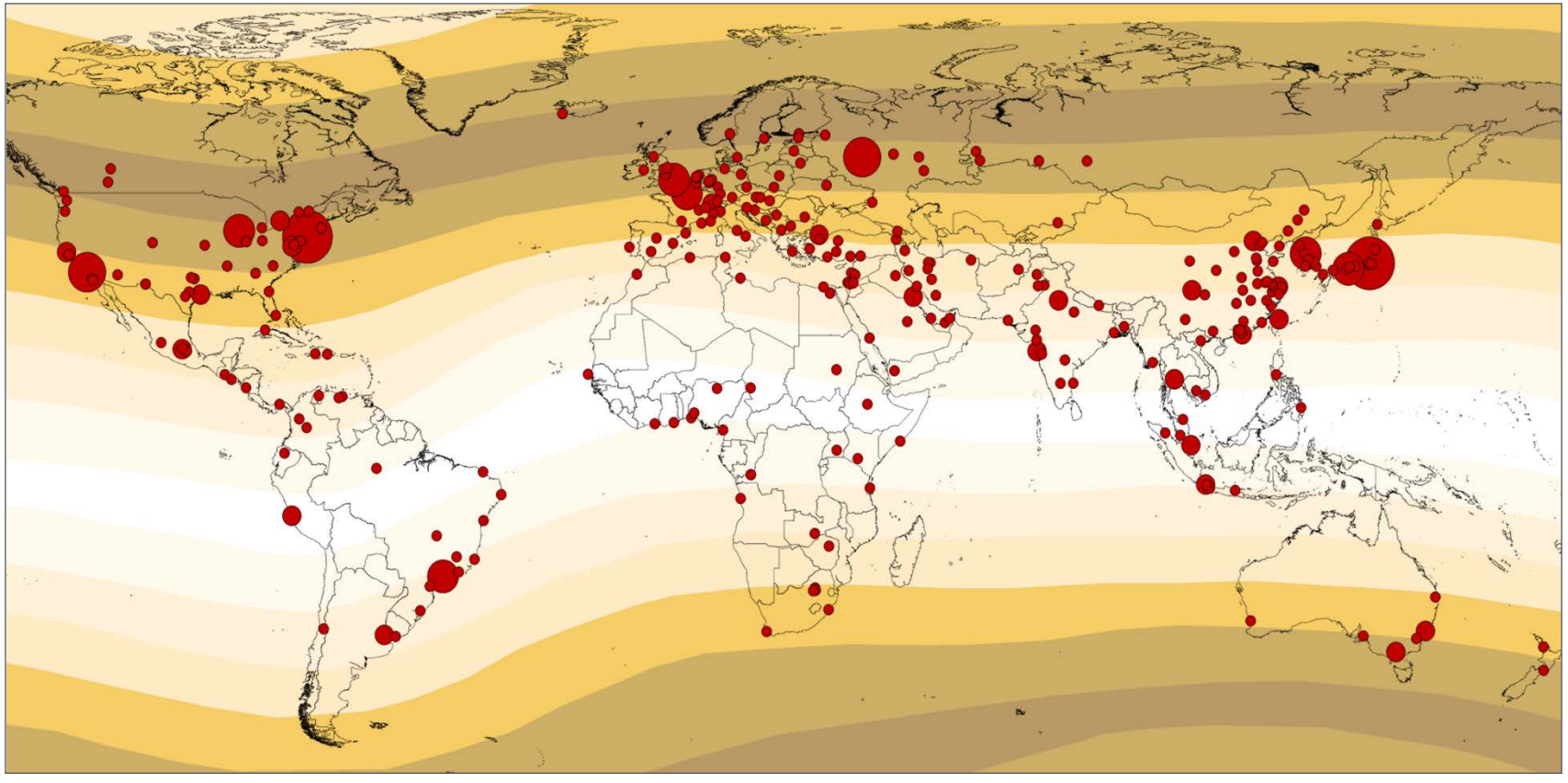
Solar Storm



City GDP@Risk (US$ Bn)

- 0.00 - 0.48
- 0.48 - 0.96
- 0.96 - 1.45
- 1.45 - 1.93
- 1.93 - 2.42

Solar Storm Threat

- A Very High Threat from Solar Storm Events
- B High Threat from Solar Storm Events
- C Moderate Threat from Solar Storm Events
- D Moderately Low Threat from Solar Storm Events
- E Low Threat from Solar Storm Events
- F Very Low Threat from Solar Storm Events

Solar activity can create geomagnetic and solar radiation storms on earth which can damage electrical circuitry and power transmission systems. These are generated by X-class solar flares, of magnitudes 20 and above, as highlighted in Lloyd's emerging risk report. The observed frequency of solar flares of different magnitudes since 1976 provides extreme value likelihoods for very large solar flares. Their effects on the earth are amplified by the geomagnetic field, as mapped above. Cities located in the strongest geomagnetic latitudes will be worse affected. The study uses the Space Weather Scale for Solar Radiation Storms defined by the US National Oceanic and Atmospheric Administration, to define characteristic scenarios for evaluation of effects on individual cities.

SS1 Radiation storm level S4, equivalent to solar flare of X20.

SS2 Radiation storm level S5 equivalent to solar flare of X40 (Similar to 'Carrington Event')

SS3 Radiation storm level S6+ (Beyond 5-point NOAA Scale). Estimated effects of solar flare of X60 - also known as a class Z event.

Top 10 Cities by GDP@Risk ($US Bn)

1	JPN	**Tokyo**	2
2	USA	**New York**	2
3	RUS	**Moscow**	1
4	USA	**Los Angeles**	1
5	FRA	**Paris**	1
6	GBR	**London**	1
7	KOR	**Seoul**	1
8	USA	**Chicago**	1
9	BRA	**São Paulo**	.9
10	JPN	**Osaka**	.9

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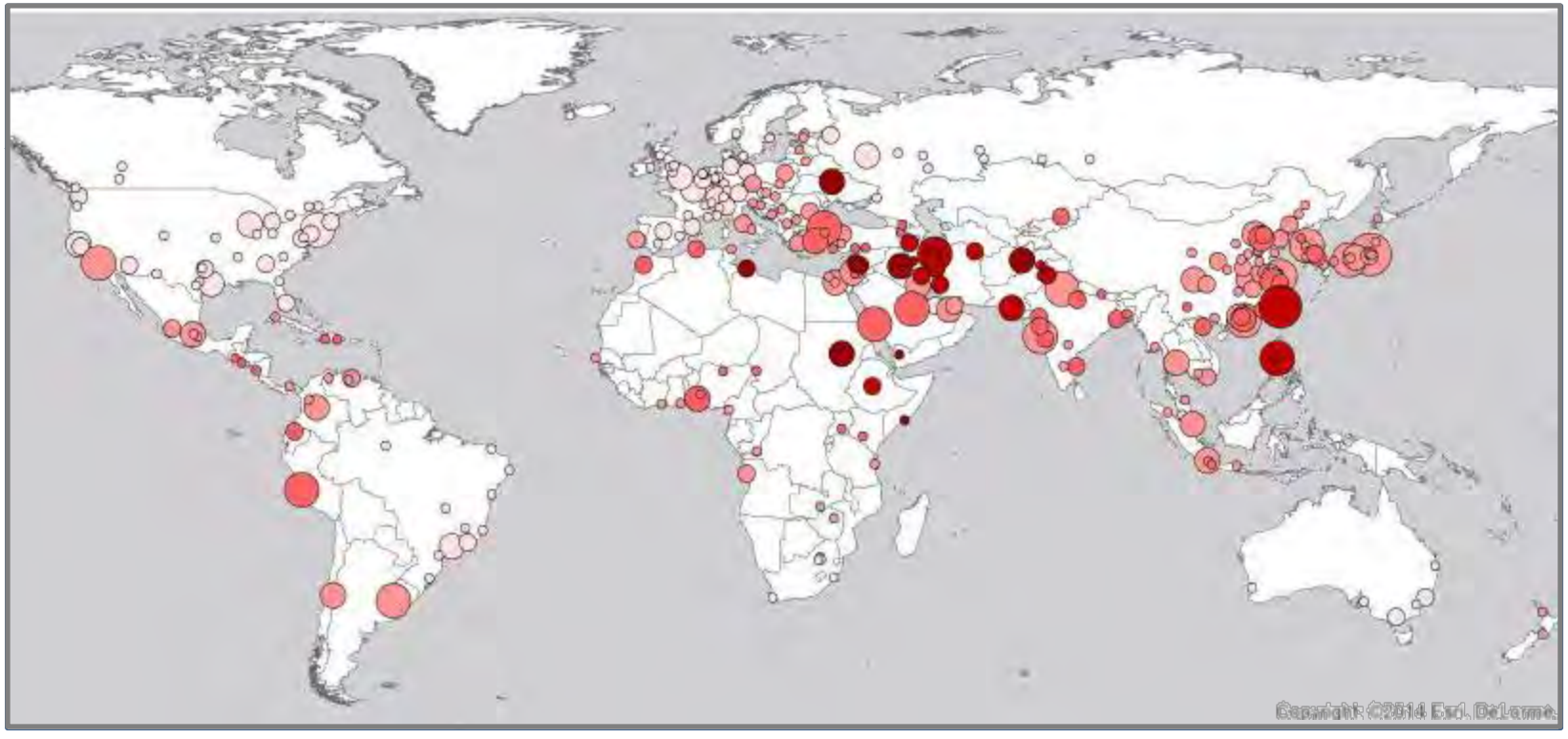
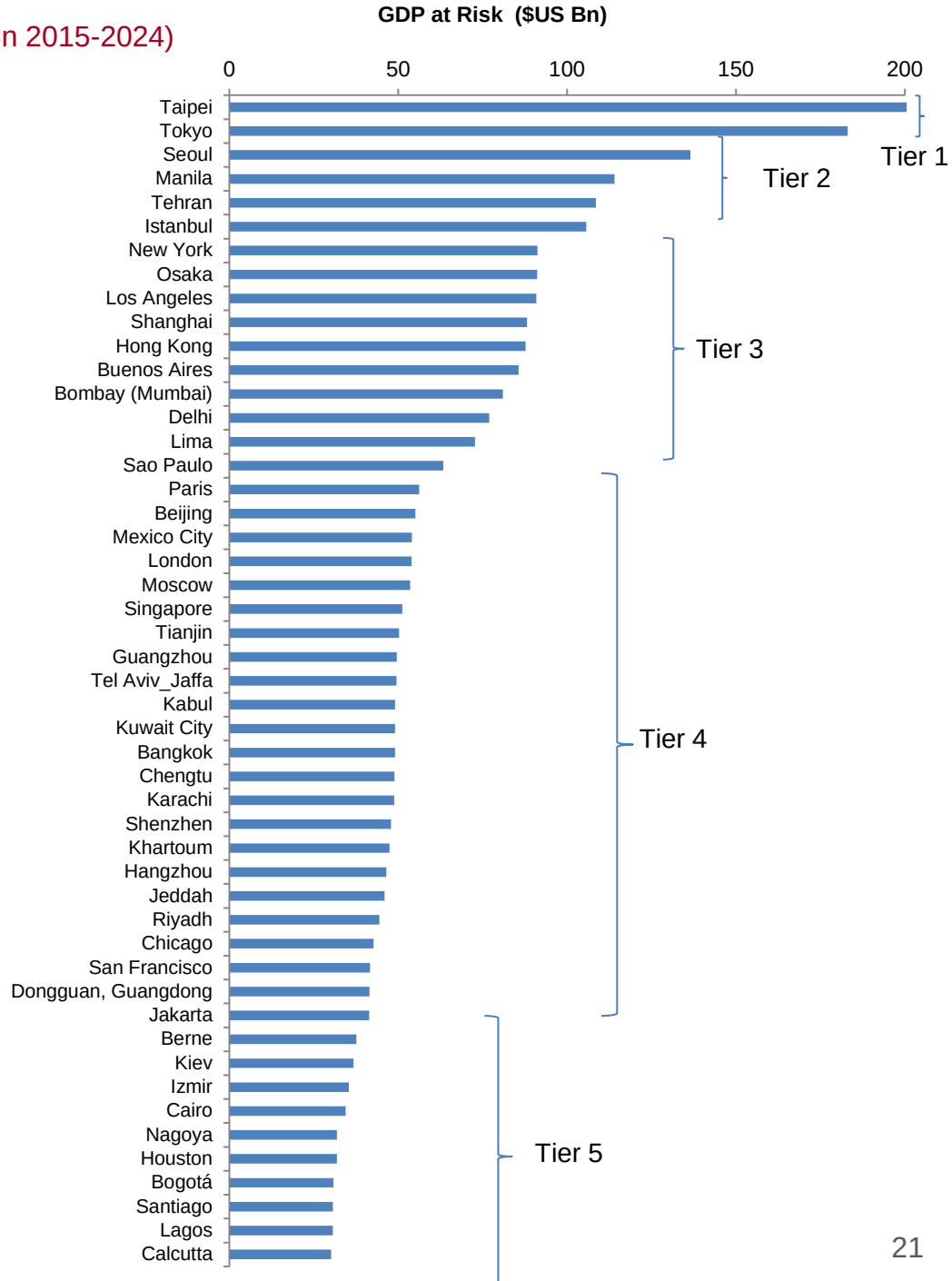
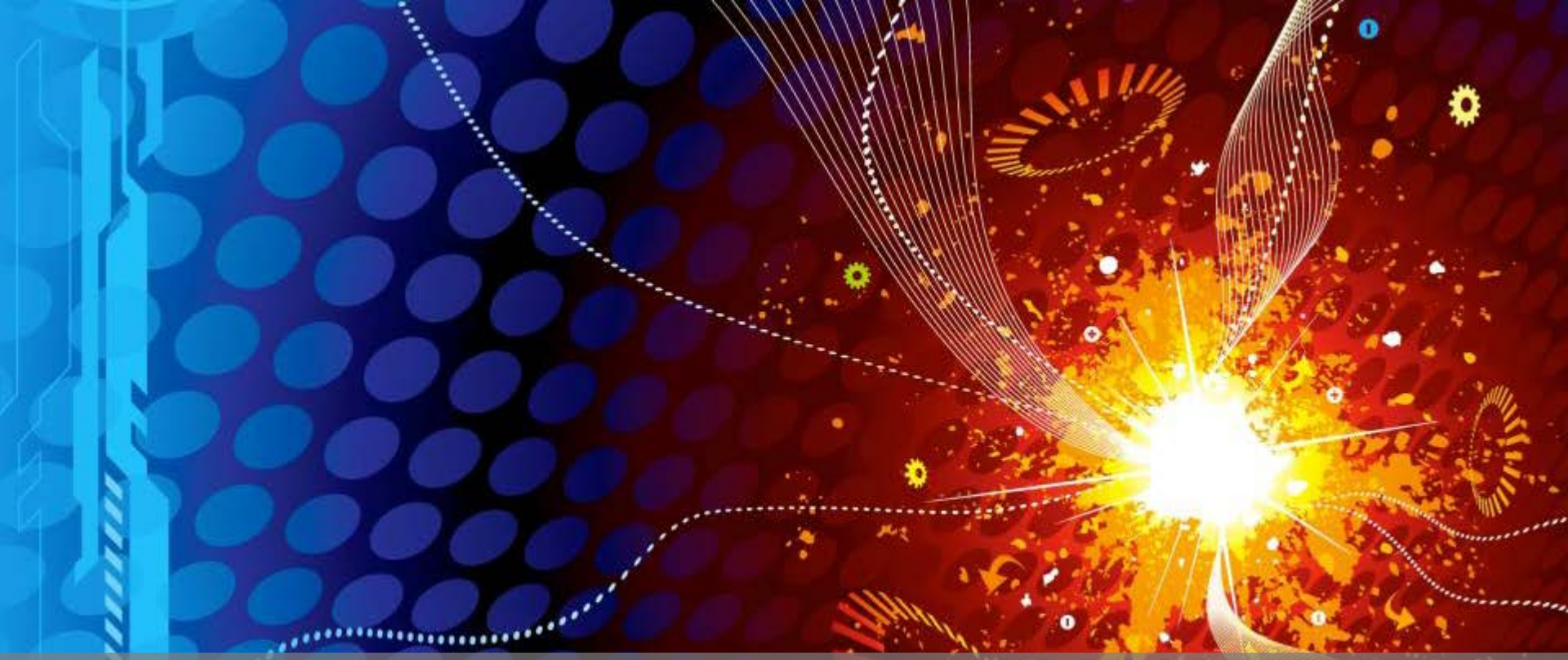
GDP@Risk


Cities - GDP at Risk - Total US$ (Bn)
0.0 - 12.0
12.1 - 30.0
30.1 - 65.0
65.1 - 115.0
115.1 - 217.0
Cities - GDP at Risk - Total %
0 - 1
1 - 2
2 - 3
3 - 6
6 - 12

Top 50 Cities by GDP at Risk ($Bn 2015-2024)

Rank	City Name	GDP@Risk ($US Bn)
1	**Taipei**	201.62
2	**Tokyo**	183.07
3	Seoul	136.52
4	Manila	114.02
5	Tehran	108.50
6	Istanbul	105.65
7	New York	91.25
8	Osaka	91.11
9	Los Angeles	90.84
10	Shanghai	88.15
11	Hong Kong	87.72
12	Buenos Aires	85.60
13	Bombay (Mumbai)	80.99
14	Delhi	76.96
15	Lima	72.69
16	Sao Paulo	63.36
17	Paris	56.23
18	Beijing	55.10
19	Mexico City	54.04
20	London	53.92
21	Moscow	53.52
22	Singapore	51.18
23	Tianjin	50.24
24	Guangzhou	49.56
25	Tel Aviv_Jaffa	49.48
26	Kabul	49.05
27	Kuwait City	49.04
28	Bangkok	49.04
29	Chengtu	48.86
30	Karachi	48.79
31	Shenzhen	47.83
32	Khartoum	47.43
33	Hangzhou	46.46
34	Jeddah	45.93
36	Riyadh	44.43
37	Chicago	42.67
38	San Francisco	41.63
39	Dongguan, Guangdong	41.51
40	Jakarta	41.42
41	Berne	37.59
42	Kiev	36.73
43	Izmir	35.40
44	Cairo	34.42
45	Nagoya	31.84
46	Houston	31.83
47	Bogotá	30.77
48	Santiago	30.66
49	Lagos	30.64
50	Calcutta	30.12





Centre for Risk Studies Research Showcase 13 January 2015

Session 1: Cambridge Risk Framework

Digital Exploration Tool

Centre for Risk Studies

UNIVERSITY OF CAMBRIDGE Judge Business School

Simon Ruffle

Director of Technology Research and Innovation

Centre for Risk Studies

Digital Exploration Tool: Main Outcomes for CRS

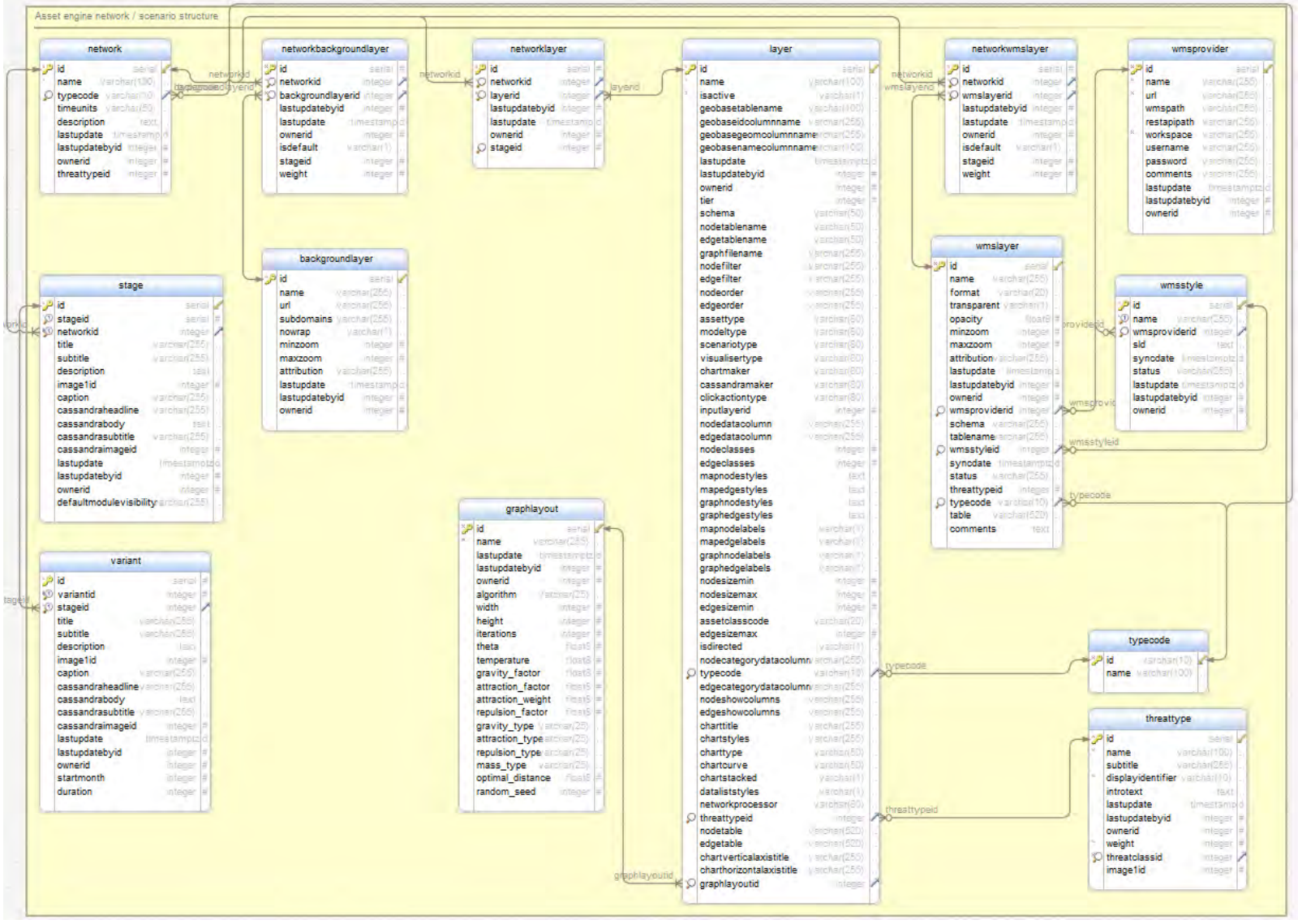
sybil.cambridgeriskframework.com

- Development of the tool has significantly advanced the research frontier of the Cambridge Risk Framework
- Proves the concept of a tool to explore a catastrophe scenario online
- Basis for future research and development of interactive risk assessment in a variety of areas
- Has helped in development of the underlying relational database for storing scenarios

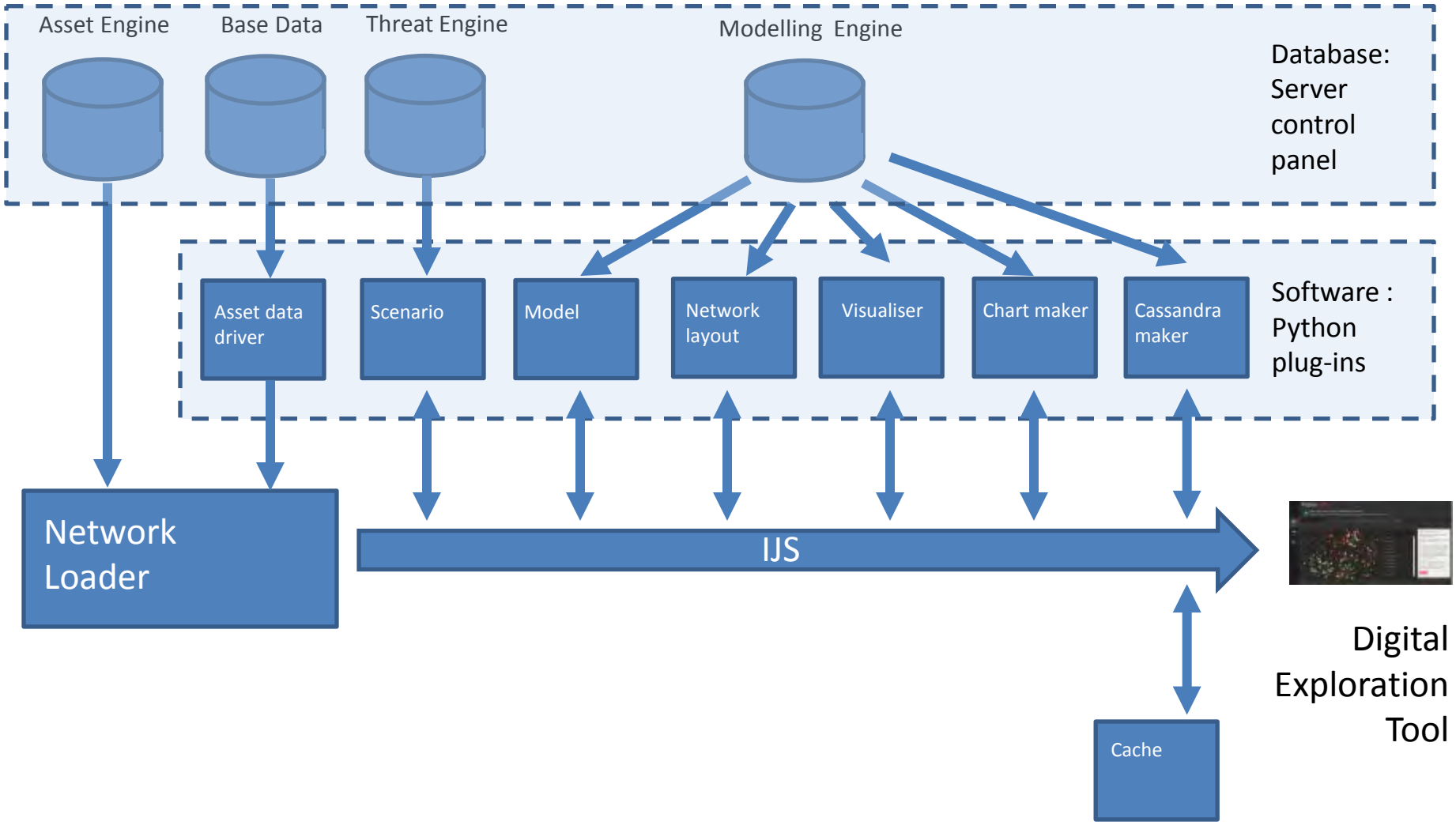
Technical Highlights

- Modular client/server architecture separating dynamic digital exploration GUI from back end data, modelling and analytics
- Based on open-source industry-standard development tools
- Web control panel facilitates team working on the Tool in the Risk Centre
- Flexible Relational Database and Intermediate JSON Structure (IJS) allows integration with a wide range of data analytic tools
- Server side Python plug in architecture aids collaboration inside Risk Centre and with research partners

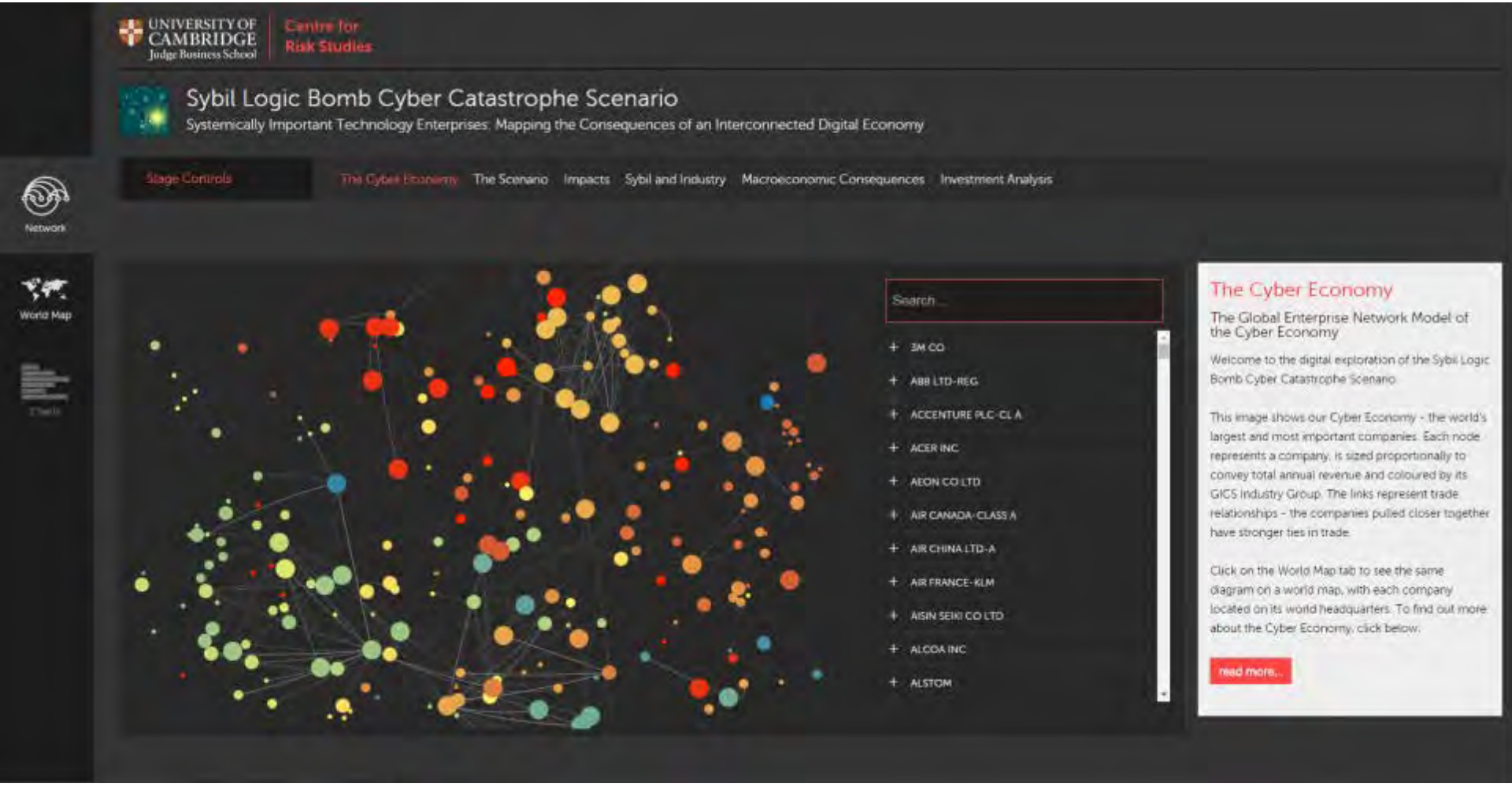
Asset Engine Database Structure



Server Side Plug In Architecture



Digital Exploration Tool: Sample Screenshots



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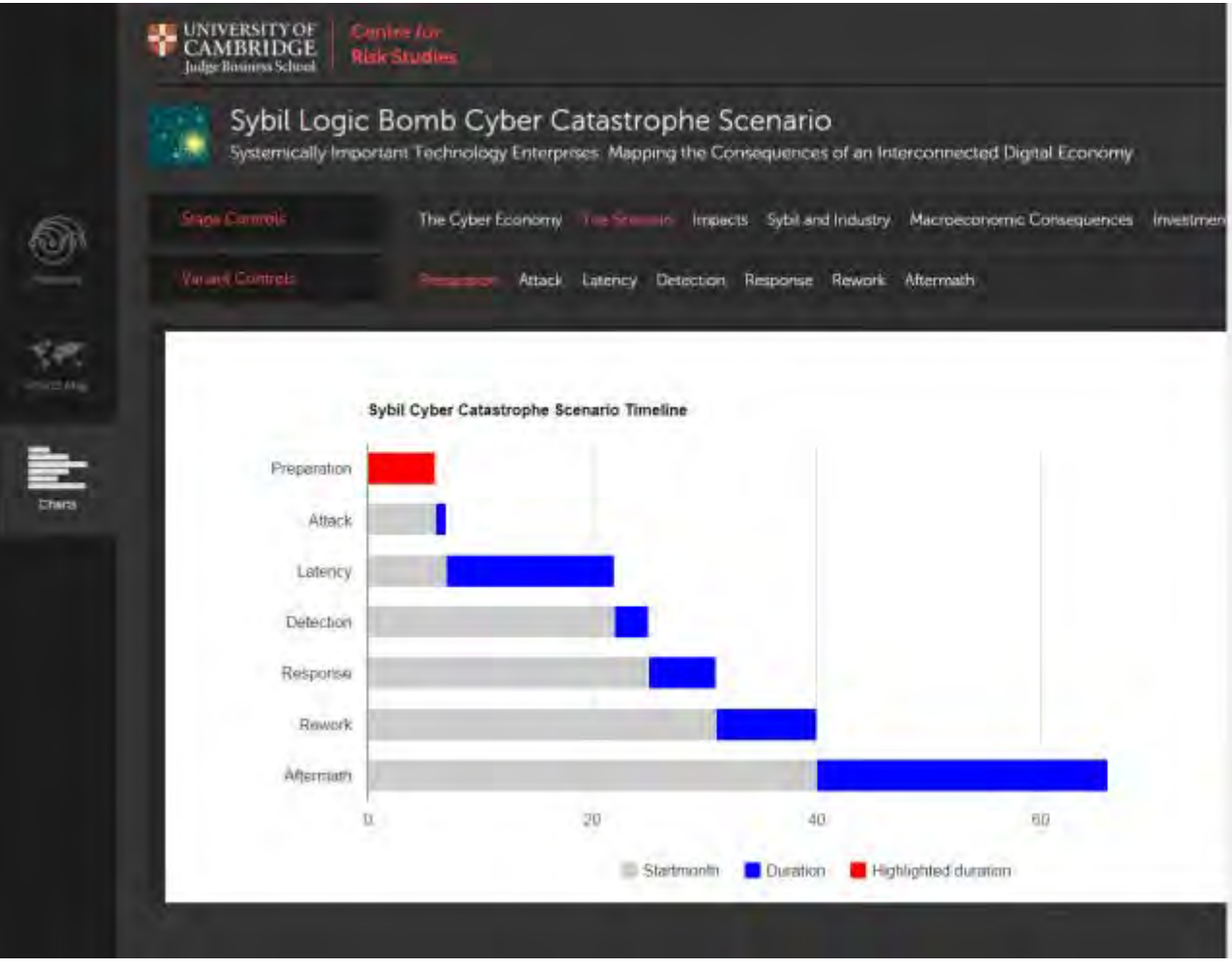

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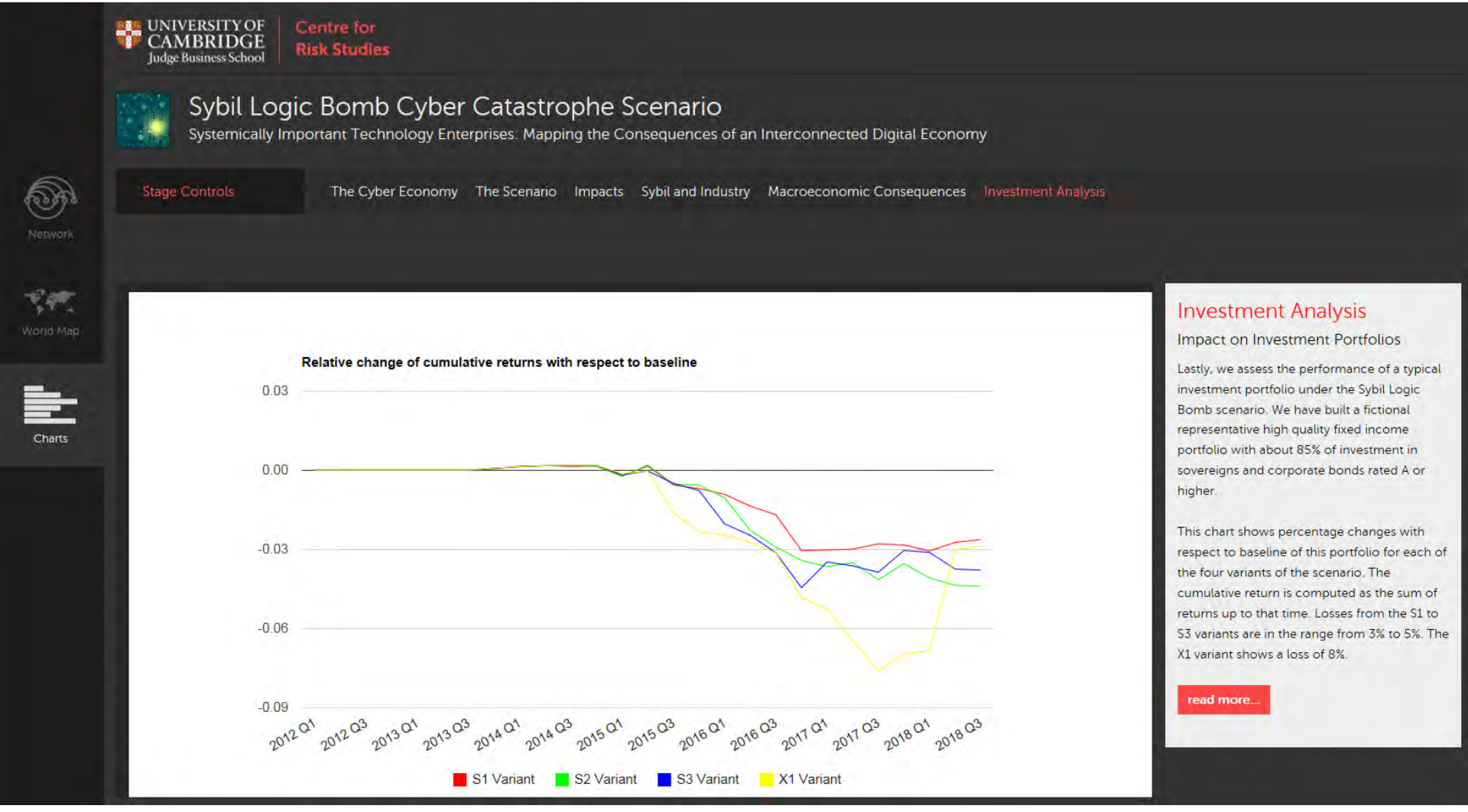

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