US012282564B2

(12) **United States Patent**
Vadala et al.

(10) **Patent No.: US 12,282,564 B2**
(45) **Date of Patent: Apr. 22, 2025**

(54) **SYSTEMS AND METHODS FOR ASSESSMENT OF CYBER RESILIENCE**

(71) Applicant: **BitSight Technologies, Inc.**, Boston, MA (US)

(72) Inventors: **Derek Vadala**, Wading River, NY (US); **Sean Malone**, Lynnwood, WA (US); **John Freund**, Huntersville, NC (US); **Vincent Dasta**, Grayslake, IL (US); **Joan Roserie**, Charlotte, NC (US)

(73) Assignee: **BitSight Technologies, Inc.**, Boston, MA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 106 days.

(21) Appl. No.: **18/162,154**

(22) Filed: **Jan. 31, 2023**

(65) **Prior Publication Data**

US 2023/0244794 A1 Aug. 3, 2023

Related U.S. Application Data

(60) Provisional application No. 63/305,082, filed on Jan. 31, 2022.

(51) **Int. Cl.**

G06F 21/57	(2013.01)
G06F 30/20	(2020.01)
G06F 111/08	(2020.01)

(52) **U.S. Cl.**

CPC ***G06F 21/577*** (2013.01); ***G06F 30/20*** (2020.01); *G06F 2111/08* (2020.01); *G06F 2221/034* (2013.01)

(58) **Field of Classification Search**

CPC G06F 21/577; G06F 30/20; G06F 2111/08; G06F 2221/034

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,867,799	A	2/1999	Lang et al.
6,016,475	A	1/2000	Miller et al.

(Continued)

FOREIGN PATENT DOCUMENTS

WO	WO-2017/142694 A1	1/2019
WO	WO-2019/023045 A1	1/2019

OTHER PUBLICATIONS

U.S. Appl. No. 15/271,655 Published as: US 2018/0083999, Self-Published Security Risk Management, filed Sep. 21, 2016.

(Continued)

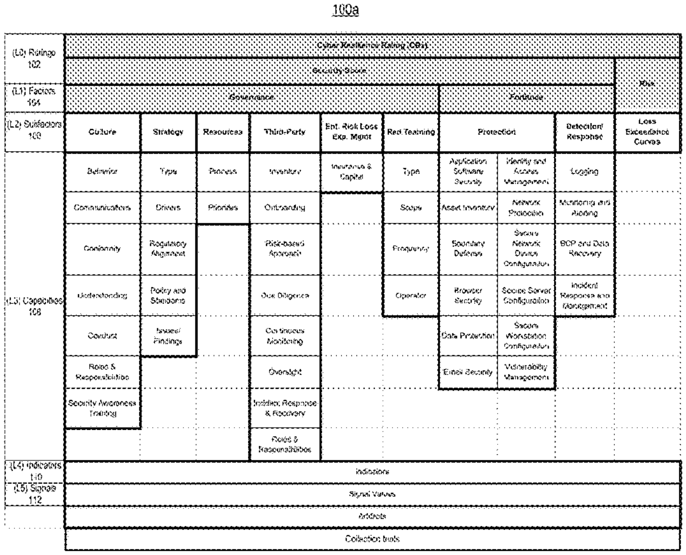
Primary Examiner — Normin Abedin

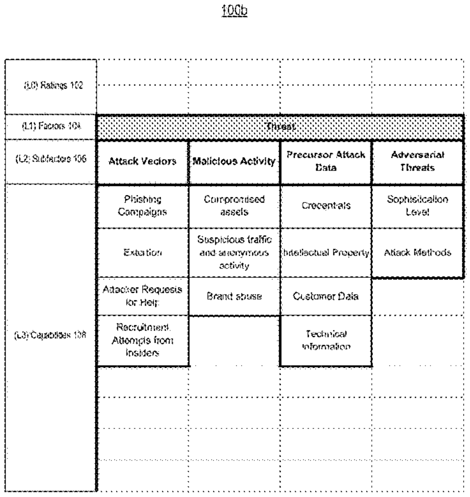
(74) *Attorney, Agent, or Firm* — Goodwin Procter LLP

(57) **ABSTRACT**

Systems and methods are disclosed for providing a cyber resilience rating. A method can include obtaining a plurality of entity indicators. The method can include determining a peer group of entities for the entity based on the entity indicators. The method can include obtaining a plurality of loss event records for the peer group. The method can include executing, based on the loss event records, a plurality of Monte Carlo simulations to generate loss simulation data. The method can include identifying, based on the loss simulation data, an expected probability value. The method can include providing a risk factor score indicative of a cyber security risk of the entity based on the identified expected probability value. The method can include providing a cyber resilience rating for the entity based on a combination of the risk factor score, a fortitude factor score, and a governance factor score.

20 Claims, 5 Drawing Sheets





(56) **References Cited**

U.S. PATENT DOCUMENTS

6,578,066	B1	6/2003	Logan et al.
6,745,150	B1	6/2004	Breiman
6,785,732	B1	8/2004	Bates et al.
6,792,401	B1	9/2004	Nigro et al.
7,062,572	B1	6/2006	Hampton
D525,264	S	7/2006	Chotai et al.
D525,629	S	7/2006	Chotai et al.
7,100,195	B1	8/2006	Underwood
7,124,055	B2	10/2006	Breiman
7,194,769	B2	3/2007	Lippmann et al.
7,257,630	B2	8/2007	Cole et al.
7,290,275	B2	10/2007	Baudoin et al.
7,343,626	B1	3/2008	Gallagher
7,389,262	B1	6/2008	Lange
7,409,357	B2	8/2008	Schaf et al.
D604,740	S	11/2009	Matheny et al.
7,650,570	B2	1/2010	Torrens et al.
7,747,778	B1	6/2010	King et al.
7,748,038	B2	6/2010	Olivier et al.
7,827,607	B2	11/2010	Sobel et al.
D630,645	S	1/2011	Tokunaga et al.
7,971,252	B2	6/2011	Lippmann et al.
8,000,698	B2	8/2011	Wolman et al.
8,042,184	B1	10/2011	Batenin
8,056,132	B1	11/2011	Chang et al.
D652,048	S	1/2012	Joseph
8,150,538	B2	4/2012	Dubinsky
8,239,939	B2	8/2012	Dunagan et al.
D667,022	S	9/2012	LoBosco et al.
8,266,695	B1	9/2012	Clay, IV
8,321,791	B2	11/2012	Dixon et al.
8,359,651	B1	1/2013	Wu et al.
8,370,933	B1	2/2013	Buckler
8,370,938	B1	2/2013	Daswani et al.
8,429,630	B2	4/2013	Nickolov et al.
D682,287	S	5/2013	Cong et al.
D688,260	S	8/2013	Pearcy et al.
8,504,556	B1	8/2013	Rice et al.
8,505,094	B1	8/2013	Xuewen et al.
D691,164	S	10/2013	Lim et al.
D694,252	S	11/2013	Helm
D694,253	S	11/2013	Helm
8,578,496	B1	11/2013	Krishnappa
8,578,499	B1	11/2013	Zhu et al.
8,584,233	B1	11/2013	Yang et al.
D696,677	S	12/2013	Corcoran et al.
8,601,575	B2	12/2013	Mullarkey et al.
8,621,621	B1	12/2013	Burns et al.
8,661,146	B2	2/2014	Alex et al.
D700,616	S	3/2014	Chao
8,677,481	B1	3/2014	Lee
8,683,584	B1	3/2014	Daswani et al.
8,752,183	B1	6/2014	Heiderich et al.
8,775,402	B2	7/2014	Baskerville et al.
8,776,240	B1	7/2014	Wu et al.
8,806,646	B1	8/2014	Daswani et al.
8,825,662	B1	9/2014	Kingman et al.
8,839,432	B1	9/2014	Patil
8,850,570	B1	9/2014	Ramzan
8,898,776	B2	11/2014	Molnar et al.
D719,969	S	12/2014	Ebtekar et al.
8,949,988	B2	2/2015	Adams et al.
8,949,990	B1	2/2015	Hsieh et al.
8,966,639	B1	2/2015	Roytman et al.
D727,942	S	4/2015	Angelides
9,015,263	B2	4/2015	Styler et al.
D730,918	S	6/2015	Park et al.
9,049,222	B1	6/2015	He et al.
9,053,210	B2	6/2015	Elnikety et al.
9,075,990	B1	7/2015	Yang
D740,847	S	10/2015	Yampolskiy et al.
D740,848	S	10/2015	Bolts et al.
D741,351	S	10/2015	Kito et al.
D746,832	S	1/2016	Pearcy et al.
9,241,252	B2	1/2016	Dua et al.
9,244,899	B1	1/2016	Greenbaum
9,294,498	B1	3/2016	Yampolskiy et al.
D754,690	S	4/2016	Park et al.
D754,696	S	4/2016	Follett et al.
9,323,930	B1	4/2016	Satish
D756,371	S	5/2016	Bertnick et al.
D756,372	S	5/2016	Bertnick et al.
D756,392	S	5/2016	Yun et al.
D757,070	S	5/2016	Dziuba
D759,073	S	6/2016	Winklevoss
D759,084	S	6/2016	Yampolskiy et al.
D759,689	S	6/2016	Olson et al.
9,372,994	B1	6/2016	Yampolskiy et al.
9,373,144	B1	6/2016	Ng et al.
D760,782	S	7/2016	Kendler et al.
9,384,206	B1	7/2016	Bono et al.
9,401,926	B1	7/2016	Dubow et al.
9,407,658	B1	8/2016	Kuskov et al.
9,413,774	B1	8/2016	Liu et al.
9,420,049	B1	8/2016	Talmor et al.
9,424,333	B1	8/2016	Bisignani et al.
9,432,383	B2	8/2016	Johns et al.
D766,952	S	9/2016	Gedrich et al.
9,438,615	B2	9/2016	Gladstone et al.
9,479,526	B1	10/2016	Yang
D771,103	S	11/2016	Eder
D771,695	S	11/2016	Yampolskiy et al.
D772,276	S	11/2016	Yampolskiy et al.
9,501,647	B2	11/2016	Yampolskiy et al.
D773,507	S	12/2016	Sagrillo et al.
D774,068	S	12/2016	Derby et al.
9,530,016	B1	12/2016	Pomerantz
D775,635	S	1/2017	Raji et al.
D776,136	S	1/2017	Chen et al.
D776,153	S	1/2017	Yampolskiy et al.
D777,177	S	1/2017	Chen et al.
9,548,988	B1	1/2017	Roundy et al.
9,560,072	B1	1/2017	Xu
D778,927	S	2/2017	Bertnick et al.
D778,928	S	2/2017	Bertnick et al.
D779,512	S	2/2017	Kimura et al.
D779,514	S	2/2017	Baris et al.
D779,531	S	2/2017	List et al.
9,578,048	B1	2/2017	Hunt et al.
D780,770	S	3/2017	Sum et al.
D785,009	S	4/2017	Lim et al.
D785,010	S	4/2017	Bachman et al.
D785,016	S	4/2017	Berwick et al.
9,620,079	B2	4/2017	Curtis
D787,530	S	5/2017	Huang
D788,128	S	5/2017	Wada
9,641,547	B2	5/2017	Yampolskiy et al.
9,646,110	B2	5/2017	Byrne et al.
D789,947	S	6/2017	Sun
D789,957	S	6/2017	Wu et al.
9,680,855	B2	6/2017	Schultz et al.
9,680,858	B1	6/2017	Boyer et al.
D791,153	S	7/2017	Rice et al.
D791,166	S	7/2017	Sandhu et al.
D791,834	S	7/2017	Eze et al.
D792,427	S	7/2017	Weaver et al.
D794,666	S	8/2017	Havaldar et al.
D794,667	S	8/2017	Havaldar et al.
D795,891	S	8/2017	Kohan et al.
9,736,019	B2	8/2017	Hardison et al.
9,742,796	B1	8/2017	Salsamendi
9,749,336	B1	8/2017	Zhang et al.
D796,523	S	9/2017	Bhandari et al.
D797,138	S	9/2017	Reiter et al.
D801,989	S	11/2017	Iketsuki et al.
D803,237	S	11/2017	Wu et al.
9,813,440	B1	11/2017	Hoover et al.
9,825,976	B1	11/2017	Gomez et al.
9,825,984	B1	11/2017	Hoover et al.
D804,528	S	12/2017	Martin et al.
D806,735	S	1/2018	Olsen et al.
D806,737	S	1/2018	Chung et al.
D807,379	S	1/2018	Pahwa et al.
9,880,710	B1	1/2018	Mackinlay et al.

(56) **References Cited**

U.S. PATENT DOCUMENTS

D809,523	S	2/2018	Lipka et al.
D809,989	S	2/2018	Lee et al.
D810,100	S	2/2018	Govindan Sankar Selvan et al.
D812,633	S	3/2018	Saneii
D814,483	S	4/2018	Gavaskar et al.
D815,119	S	4/2018	Chalker et al.
D815,148	S	4/2018	Martin et al.
D816,105	S	4/2018	Rudick et al.
D816,116	S	4/2018	Selassie
9,954,893	B1	4/2018	Zhao et al.
D817,970	S	5/2018	Chang et al.
D817,977	S	5/2018	Kato et al.
D818,475	S	5/2018	Yepez et al.
9,973,524	B2	5/2018	Boyer et al.
D819,687	S	6/2018	Yampolskiy et al.
D824,954	S	8/2018	Parfentieva et al.
10,044,750	B2	8/2018	Livshits et al.
D829,239	S	9/2018	Rehman
10,079,854	B1	9/2018	Scott et al.
10,084,817	B2	9/2018	Saher et al.
10,142,364	B2	11/2018	Baukes et al.
D835,631	S	12/2018	Yepez et al.
10,180,966	B1	1/2019	Lang et al.
10,185,924	B1	1/2019	McClintock et al.
10,210,329	B1	2/2019	Malik et al.
10,217,071	B2	2/2019	Mo et al.
10,230,753	B2	3/2019	Yampolskiy et al.
10,230,764	B2	3/2019	Ng et al.
10,235,524	B2	3/2019	Ford
10,242,180	B2	3/2019	Haefner et al.
D847,147	S	4/2019	Wesley et al.
D847,169	S	4/2019	Sombreireiro et al.
10,257,219	B1	4/2019	Geil et al.
10,305,854	B2	5/2019	Alizadeh-Shabdiz et al.
10,331,502	B1	6/2019	Hart
D853,413	S	7/2019	Hofner et al.
10,339,321	B2	7/2019	Tedeschi
10,339,484	B2	7/2019	Pai et al.
10,348,755	B1	7/2019	Shavell et al.
10,412,083	B2	9/2019	Zou et al.
D863,335	S	10/2019	Hardy et al.
D863,345	S	10/2019	Hardy et al.
D864,219	S	10/2019	Farnan et al.
10,453,142	B2	10/2019	Mun
10,469,515	B2	11/2019	Helmsen et al.
10,482,239	B1	11/2019	Liu et al.
10,491,619	B2	11/2019	Yampolskiy et al.
10,491,620	B2	11/2019	Yampolskiy et al.
10,521,583	B1	12/2019	Bagulho Monteiro Pereira
D872,574	S	1/2020	Deylamian et al.
10,540,374	B2	1/2020	Singh et al.
D874,506	S	2/2020	Kang et al.
10,558,546	B2	2/2020	Cranfill et al.
10,572,945	B1	2/2020	McNair
D880,512	S	4/2020	Greenwald et al.
D894,939	S	9/2020	Braica
10,764,298	B1	9/2020	Light et al.
10,776,483	B2	9/2020	Bagulho Monteiro Pereira
D900,145	S	10/2020	Malahy et al.
10,796,260	B2	10/2020	Brannon et al.
10,805,331	B2	10/2020	Boyer et al.
D903,693	S	12/2020	Li et al.
D905,712	S	12/2020	Li et al.
D905,730	S	12/2020	Newsom
D908,139	S	1/2021	Hardy et al.
10,896,394	B2	1/2021	Brannon et al.
D910,705	S	2/2021	Capela et al.
10,909,488	B2	2/2021	Hecht et al.
D914,719	S	3/2021	Ryan et al.
D914,732	S	3/2021	Fischbach
D918,955	S	5/2021	Madden, Jr. et al.
D920,343	S	5/2021	Bowland
D920,353	S	5/2021	Boutros et al.
D921,031	S	6/2021	Tessier et al.
D921,662	S	6/2021	Giannino et al.
D921,674	S	6/2021	Kmak et al.
D921,677	S	6/2021	Kmak et al.
D922,397	S	6/2021	Modi et al.
D924,901	S	7/2021	Garg et al.
D924,909	S	7/2021	Nasu et al.
D931,867	S	9/2021	Okumura et al.
11,122,073	B1	9/2021	Cai et al.
11,126,723	B2	9/2021	Bagulho Monteiro Pereira
D940,742	S	1/2022	Vickers et al.
D946,596	S	3/2022	Ahmed
D947,238	S	3/2022	Nie et al.
D949,884	S	4/2022	Capela et al.
11,334,832	B2	5/2022	Dumoulin et al.
11,379,773	B2	7/2022	Vescio
D960,191	S	8/2022	Feit et al.
D960,924	S	8/2022	Nordstrom et al.
11,455,322	B2	9/2022	Yang et al.
D971,933	S	12/2022	Ahmed
D982,604	S	4/2023	Pacione et al.
D983,820	S	4/2023	Dunnette et al.
D987,668	S	5/2023	Mairs et al.
11,652,834	B2	5/2023	Gladstone et al.
D991,943	S	7/2023	Fawcett et al.
11,727,114	B2	8/2023	Bagulho Monteiro Pereira
11,777,976	B2	10/2023	Boyer et al.
D1,008,289	S	12/2023	Yazdansepas
D1,010,666	S	1/2024	Cai
D1,010,677	S	1/2024	Clymer
D1,014,517	S	2/2024	Russell
2001/0044798	A1	11/2001	Nagral et al.
2002/0083077	A1	6/2002	Vardi
2002/0133365	A1	9/2002	Grey et al.
2002/0164983	A1	11/2002	Raviv et al.
2003/0011601	A1	1/2003	Itoh et al.
2003/0050862	A1	3/2003	Bleicken et al.
2003/0074248	A1	4/2003	Braud et al.
2003/0123424	A1	7/2003	Jung
2003/0187967	A1	10/2003	Walsh et al.
2004/0003284	A1	1/2004	Campbell et al.
2004/0010709	A1	1/2004	Baudoin et al.
2004/0024859	A1	2/2004	Bloch et al.
2004/0088570	A1	5/2004	Roberts et al.
2004/0098375	A1	5/2004	DeCarlo
2004/0111358	A1	6/2004	Lange et al.
2004/0133561	A1	7/2004	Burke
2004/0133689	A1	7/2004	Vasisht
2004/0193907	A1	9/2004	Patanella
2004/0193918	A1	9/2004	Green et al.
2004/0199791	A1	10/2004	Poletto et al.
2004/0199792	A1	10/2004	Tan et al.
2004/0221296	A1	11/2004	Ogielski et al.
2004/0250122	A1	12/2004	Newton
2004/0250134	A1	12/2004	Kohler et al.
2005/0065754	A1	3/2005	Schaf et al.
2005/0065807	A1	3/2005	DeAngelis et al.
2005/0066195	A1	3/2005	Jones
2005/0071450	A1	3/2005	Allen et al.
2005/0076245	A1	4/2005	Graham et al.
2005/0080720	A1	4/2005	Betz et al.
2005/0108415	A1	5/2005	Turk et al.
2005/0131830	A1	6/2005	Juarez et al.
2005/0138413	A1	6/2005	Lippmann et al.
2005/0160002	A1	7/2005	Roetter et al.
2005/0228899	A1	10/2005	Wendkos et al.
2005/0234767	A1	10/2005	Bolzman et al.
2005/0278726	A1	12/2005	Cano et al.
2005/0278786	A1	12/2005	Tippett et al.
2006/0036335	A1	2/2006	Banter et al.
2006/0075490	A1	4/2006	Boney et al.
2006/0075494	A1	4/2006	Bertman et al.
2006/0107226	A1	5/2006	Matthews et al.
2006/0173992	A1	8/2006	Weber et al.
2006/0212925	A1	9/2006	Shull et al.
2006/0230039	A1	10/2006	Shull et al.
2006/0253458	A1	11/2006	Dixon et al.
2006/0253581	A1	11/2006	Dixon et al.
2006/0271564	A1	11/2006	Meng Muntz et al.
2007/0016948	A1	1/2007	Dubrovsky et al.
2007/0067845	A1	3/2007	Wiemer et al.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2007/0113282	A1	5/2007	Ross
2007/0136622	A1	6/2007	Price et al.
2007/0143851	A1	6/2007	Nicodemus et al.
2007/0174915	A1	7/2007	Gribble et al.
2007/0179955	A1	8/2007	Croft et al.
2007/0198275	A1	8/2007	Malden et al.
2007/0214151	A1	9/2007	Thomas et al.
2007/0282730	A1	12/2007	Carpenter et al.
2008/0017526	A1	1/2008	Prescott et al.
2008/0033775	A1	2/2008	Dawson et al.
2008/0047018	A1	2/2008	Baudoin et al.
2008/0091834	A1	4/2008	Norton
2008/0097980	A1	4/2008	Sullivan
2008/0127338	A1	5/2008	Cho et al.
2008/0140495	A1	6/2008	Bhamidipaty et al.
2008/0140728	A1	6/2008	Fraser et al.
2008/0148408	A1	6/2008	Kao et al.
2008/0162931	A1	7/2008	Lord et al.
2008/0172382	A1	7/2008	Prettejohn
2008/0175266	A1	7/2008	Alperovitch et al.
2008/0208995	A1	8/2008	Takahashi et al.
2008/0209565	A2	8/2008	Baudoin et al.
2008/0222287	A1	9/2008	Bahl et al.
2008/0222736	A1	9/2008	Boodaei et al.
2008/0262895	A1	10/2008	Hofmeister et al.
2008/0270458	A1	10/2008	Gvelesiani
2009/0019525	A1	1/2009	Yu et al.
2009/0024663	A1	1/2009	McGovern
2009/0044272	A1	2/2009	Jarrett
2009/0064337	A1	3/2009	Chien
2009/0094265	A1	4/2009	Vlachos et al.
2009/0094697	A1	4/2009	Provos et al.
2009/0125427	A1	5/2009	Atwood et al.
2009/0132861	A1	5/2009	Costa et al.
2009/0147026	A1	6/2009	Buck et al.
2009/0150999	A1	6/2009	Dewey et al.
2009/0161629	A1	6/2009	Purkayastha et al.
2009/0193054	A1	7/2009	Karimisetty et al.
2009/0204235	A1	8/2009	Dubinsky
2009/0216700	A1	8/2009	Bouchard et al.
2009/0228830	A1	9/2009	Herz et al.
2009/0265787	A9	10/2009	Baudoin et al.
2009/0276835	A1	11/2009	Jackson et al.
2009/0293128	A1	11/2009	Lippmann et al.
2009/0299802	A1	12/2009	Brennan
2009/0300768	A1	12/2009	Krishnamurthy et al.
2009/0319420	A1	12/2009	Sanchez et al.
2009/0323632	A1	12/2009	Nix
2009/0328063	A1	12/2009	Corvera et al.
2010/0017880	A1	1/2010	Masood
2010/0024033	A1	1/2010	Kang et al.
2010/0042605	A1	2/2010	Cheng et al.
2010/0057582	A1	3/2010	Arfin et al.
2010/0114634	A1	5/2010	Christiansen et al.
2010/0114757	A1	5/2010	Jeng et al.
2010/0180344	A1	7/2010	Malyshev et al.
2010/0186088	A1	7/2010	Banerjee et al.
2010/0205042	A1	8/2010	Mun
2010/0218256	A1	8/2010	Thomas et al.
2010/0235910	A1	9/2010	Ku et al.
2010/0251000	A1	9/2010	Lyne et al.
2010/0251371	A1	9/2010	Brown
2010/0262444	A1	10/2010	Atwal et al.
2010/0275263	A1	10/2010	Bennett et al.
2010/0281124	A1	11/2010	Westman et al.
2010/0281151	A1	11/2010	Ramankutty et al.
2010/0309206	A1	12/2010	Xie et al.
2011/0060950	A1	3/2011	Waldron et al.
2011/0099620	A1	4/2011	Stavrou et al.
2011/0106920	A1	5/2011	Longo
2011/0137704	A1	6/2011	Mitra et al.
2011/0145168	A1	6/2011	Dirnstorfer et al.
2011/0145576	A1	6/2011	Bettan
2011/0148880	A1	6/2011	De Peuter
2011/0185403	A1	7/2011	Dolan et al.
2011/0185427	A1	7/2011	Aciicmez et al.
2011/0213742	A1	9/2011	Lemmond et al.
2011/0219455	A1	9/2011	Bhagwan et al.
2011/0225085	A1	9/2011	Takeshita et al.
2011/0231395	A1	9/2011	Vadlamani et al.
2011/0239294	A1	9/2011	Kim et al.
2011/0239300	A1	9/2011	Klein et al.
2011/0249002	A1	10/2011	Duplessis et al.
2011/0276514	A1	11/2011	Kalagnanam et al.
2011/0282997	A1	11/2011	Prince et al.
2011/0289582	A1	11/2011	Kejriwal et al.
2011/0296519	A1	12/2011	Ide et al.
2012/0008974	A1	1/2012	Kawai et al.
2012/0036263	A1	2/2012	Madden et al.
2012/0036580	A1	2/2012	Gorny et al.
2012/0059823	A1	3/2012	Barber et al.
2012/0079596	A1	3/2012	Thomas et al.
2012/0089745	A1	4/2012	Turakhia
2012/0158725	A1	6/2012	Molloy et al.
2012/0166458	A1	6/2012	Laudanski et al.
2012/0174219	A1	7/2012	Hernandez et al.
2012/0198558	A1	8/2012	Liu et al.
2012/0215892	A1	8/2012	Wanser et al.
2012/0221376	A1	8/2012	Austin
2012/0254993	A1	10/2012	Sallam
2012/0255021	A1	10/2012	Sallam
2012/0255027	A1	10/2012	Kanakapura et al.
2012/0290498	A1	11/2012	Jones
2012/0291129	A1	11/2012	Shulman et al.
2013/0014253	A1	1/2013	Neou et al.
2013/0055070	A1	2/2013	Sacks et al.
2013/0055386	A1	2/2013	Kim et al.
2013/0060351	A1	3/2013	Imming et al.
2013/0080341	A1	3/2013	Veeramachaneni et al.
2013/0080505	A1	3/2013	Nielsen et al.
2013/0086521	A1	4/2013	Grossele et al.
2013/0086681	A1	4/2013	Jaroch
2013/0086687	A1	4/2013	Chess et al.
2013/0091574	A1	4/2013	Howes et al.
2013/0124644	A1	5/2013	Hunt et al.
2013/0124653	A1	5/2013	Vick et al.
2013/0142050	A1	6/2013	Luna
2013/0145437	A1	6/2013	Zaitsev
2013/0173791	A1	7/2013	Longo
2013/0212479	A1	8/2013	Willis et al.
2013/0227078	A1	8/2013	Wei et al.
2013/0227697	A1	8/2013	Zandani
2013/0238527	A1	9/2013	Jones
2013/0263034	A1	10/2013	Bruck et al.
2013/0263270	A1	10/2013	Cote et al.
2013/0275176	A1	10/2013	Brown et al.
2013/0276056	A1	10/2013	Epstein
2013/0282406	A1	10/2013	Snyder et al.
2013/0291105	A1	10/2013	Yan
2013/0298244	A1	11/2013	Kumar et al.
2013/0305368	A1	11/2013	Ford
2013/0318594	A1	11/2013	Hoy et al.
2013/0333038	A1	12/2013	Chien
2013/0345978	A1	12/2013	Lush et al.
2013/0347116	A1	12/2013	Flores et al.
2014/0006129	A1	1/2014	Heath
2014/0019196	A1	1/2014	Wiggins et al.
2014/0040747	A1	2/2014	Gardenfors
2014/0052998	A1	2/2014	Bloom et al.
2014/0101006	A1	4/2014	Pitt
2014/0108474	A1	4/2014	David et al.
2014/0114755	A1	4/2014	Mezzacca
2014/0114843	A1	4/2014	Klein et al.
2014/0130158	A1	5/2014	Wang et al.
2014/0137254	A1	5/2014	Ou et al.
2014/0137257	A1	5/2014	Martinez et al.
2014/0146370	A1	5/2014	Banner et al.
2014/0173066	A1	6/2014	Newton et al.
2014/0173736	A1	6/2014	Liu
2014/0189098	A1	7/2014	MaGill et al.
2014/0189864	A1	7/2014	Wang et al.
2014/0204803	A1	7/2014	Nguyen et al.
2014/0206970	A1	7/2014	Wesley et al.
2014/0237545	A1	8/2014	Mylavarapu et al.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2014/0244317	A1	8/2014	Roberts et al.
2014/0282261	A1	9/2014	Ranz et al.
2014/0283056	A1	9/2014	Bachwani et al.
2014/0283067	A1	9/2014	Call et al.
2014/0283068	A1	9/2014	Call et al.
2014/0283069	A1	9/2014	Call et al.
2014/0288996	A1	9/2014	Rence et al.
2014/0304816	A1	10/2014	Klein et al.
2014/0330616	A1	11/2014	Lyras
2014/0334336	A1	11/2014	Chen et al.
2014/0337086	A1	11/2014	Asenjo et al.
2014/0337633	A1	11/2014	Yang et al.
2014/0344332	A1	11/2014	Giebler
2015/0033331	A1	1/2015	Stern et al.
2015/0033341	A1	1/2015	Schmidtler et al.
2015/0052607	A1	2/2015	Al Hamami
2015/0074579	A1	3/2015	Gladstone et al.
2015/0081860	A1	3/2015	Kuehnel et al.
2015/0088783	A1	3/2015	Mun
2015/0156084	A1	6/2015	Kaminsky et al.
2015/0180883	A1	6/2015	Aktas et al.
2015/0195299	A1	7/2015	Zoldi et al.
2015/0207776	A1	7/2015	Morin et al.
2015/0213259	A1	7/2015	Du et al.
2015/0248280	A1	9/2015	Pillay et al.
2015/0261955	A1	9/2015	Huang et al.
2015/0264061	A1	9/2015	Ibatullin et al.
2015/0288706	A1	10/2015	Marshall
2015/0288709	A1	10/2015	Singhal et al.
2015/0310188	A1	10/2015	Ford et al.
2015/0310213	A1	10/2015	Ronen et al.
2015/0317672	A1	11/2015	Espinoza et al.
2015/0331932	A1	11/2015	Georges et al.
2015/0339479	A1	11/2015	Wang et al.
2015/0347754	A1	12/2015	Born
2015/0347756	A1	12/2015	Hidayat et al.
2015/0350229	A1	12/2015	Mitchell
2015/0365587	A1	12/2015	Ha et al.
2015/0381649	A1	12/2015	Schultz et al.
2016/0014081	A1	1/2016	Don, Jr. et al.
2016/0023639	A1	1/2016	Cajiga et al.
2016/0028746	A1	1/2016	Tonn
2016/0036849	A1	2/2016	Zakian
2016/0065613	A1	3/2016	Cho et al.
2016/0078382	A1	3/2016	Watkins et al.
2016/0088015	A1	3/2016	Sivan et al.
2016/0104071	A1	4/2016	Brueckner
2016/0119373	A1	4/2016	Fausto et al.
2016/0140466	A1	5/2016	Sidebottom et al.
2016/0142419	A1	5/2016	Antipa et al.
2016/0142428	A1	5/2016	Pastore et al.
2016/0147992	A1	5/2016	Zhao et al.
2016/0162602	A1	6/2016	Bradish et al.
2016/0171415	A1	6/2016	Yampolskiy et al.
2016/0173520	A1	6/2016	Foster et al.
2016/0173522	A1	6/2016	Yampolskiy et al.
2016/0182537	A1	6/2016	Tatourian et al.
2016/0189301	A1	6/2016	Ng et al.
2016/0191554	A1	6/2016	Kaminsky
2016/0205126	A1*	7/2016	Boyer H04L 63/1433 726/25
2016/0212101	A1	7/2016	Reshadi et al.
2016/0239772	A1*	8/2016	Dahlberg G06F 16/23
2016/0241560	A1	8/2016	Reshadi et al.
2016/0248797	A1	8/2016	Yampolskiy et al.
2016/0248800	A1	8/2016	Ng et al.
2016/0253500	A1	9/2016	Alme et al.
2016/0259945	A1	9/2016	Yampolskiy et al.
2016/0291860	A1	10/2016	Higuchi et al.
2016/0335232	A1	11/2016	Born et al.
2016/0337387	A1	11/2016	Hu et al.
2016/0344769	A1	11/2016	Li
2016/0344801	A1	11/2016	Akkarawittayapoom
2016/0359875	A1	12/2016	Kim et al.
2016/0364496	A1	12/2016	Li
2016/0373485	A1	12/2016	Kamble
2016/0378978	A1	12/2016	Singla et al.
2017/0048267	A1	2/2017	Yampolskiy et al.
2017/0063901	A1	3/2017	Muddu et al.
2017/0063923	A1	3/2017	Yang et al.
2017/0104783	A1	4/2017	Vanunu et al.
2017/0126719	A1	5/2017	Mason
2017/0142148	A1	5/2017	Bußer et al.
2017/0161253	A1	6/2017	Silver
2017/0161409	A1	6/2017	Martin
2017/0213292	A1	7/2017	Sweeney et al.
2017/0221072	A1	8/2017	AthuluruTlrumala et al.
2017/0223002	A1	8/2017	Sabin et al.
2017/0236078	A1	8/2017	Rasumov
2017/0237764	A1	8/2017	Rasumov
2017/0264623	A1	9/2017	Ficarra et al.
2017/0277892	A1	9/2017	MacDermid
2017/0279843	A1	9/2017	Schultz et al.
2017/0289109	A1	10/2017	Caragea
2017/0300911	A1	10/2017	Alnajem
2017/0316324	A1	11/2017	Barrett et al.
2017/0318045	A1	11/2017	Johns et al.
2017/0324555	A1	11/2017	Wu et al.
2017/0324766	A1	11/2017	Gonzalez
2017/0337487	A1	11/2017	Nock et al.
2018/0013716	A1	1/2018	Connell et al.
2018/0041521	A1	2/2018	Zhang et al.
2018/0052999	A1	2/2018	Mitola, III
2018/0088968	A1	3/2018	Myhre et al.
2018/0103043	A1	4/2018	Kupreev et al.
2018/0121659	A1	5/2018	Sawhney et al.
2018/0123934	A1	5/2018	Gissing et al.
2018/0124091	A1	5/2018	Sweeney et al.
2018/0124110	A1	5/2018	Hunt et al.
2018/0139180	A1	5/2018	Napchi et al.
2018/0146004	A1	5/2018	Belfiore, Jr. et al.
2018/0157468	A1	6/2018	Stachura
2018/0191768	A1	7/2018	Broda et al.
2018/0218157	A1	8/2018	Price et al.
2018/0219910	A1	8/2018	Greenshpan et al.
2018/0285414	A1	10/2018	Kondiles et al.
2018/0322584	A1	11/2018	Crabtree et al.
2018/0324201	A1	11/2018	Lowry et al.
2018/0332076	A1	11/2018	Callahan et al.
2018/0336348	A1	11/2018	Ng et al.
2018/0337938	A1	11/2018	Kneib et al.
2018/0337941	A1	11/2018	Kraning et al.
2018/0349641	A1	12/2018	Barday et al.
2018/0365519	A1	12/2018	Pollard et al.
2018/0375896	A1	12/2018	Wang et al.
2018/0375953	A1	12/2018	Casassa Mont et al.
2019/0034845	A1	1/2019	Mo et al.
2019/0052650	A1	2/2019	Hu et al.
2019/0065545	A1	2/2019	Hazel et al.
2019/0065748	A1	2/2019	Foster et al.
2019/0079869	A1	3/2019	Baldi et al.
2019/0089711	A1	3/2019	Faulkner
2019/0098025	A1	3/2019	Lim
2019/0124091	A1	4/2019	Ujiie et al.
2019/0140925	A1	5/2019	Pon et al.
2019/0141060	A1	5/2019	Lim
2019/0147378	A1	5/2019	Mo et al.
2019/0163914	A1	5/2019	Steele et al.
2019/0166152	A1	5/2019	Steele et al.
2019/0166156	A1	5/2019	King-Wilson
2019/0179490	A1	6/2019	Barday et al.
2019/0215331	A1	7/2019	Anakata et al.
2019/0238439	A1	8/2019	Pugh et al.
2019/0297106	A1	9/2019	Geil et al.
2019/0303574	A1	10/2019	Lamay et al.
2019/0303584	A1	10/2019	Yang et al.
2019/0362280	A1	11/2019	Vescio
2019/0379632	A1	12/2019	Dahlberg et al.
2019/0391707	A1	12/2019	Ristow et al.
2019/0392252	A1	12/2019	Fighel et al.
2020/0012794	A1	1/2020	Saldanha et al.
2020/0053127	A1	2/2020	Brotherton et al.
2020/0065213	A1	2/2020	Poghosyan et al.
2020/0074084	A1	3/2020	Dorrans et al.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2020/0092172	A1	3/2020	Kumaran et al.	
2020/0097845	A1	3/2020	Shaikh et al.	
2020/0104488	A1	4/2020	Li et al.	
2020/0106798	A1	4/2020	Lin	
2020/0120118	A1	4/2020	Shu et al.	
2020/0125734	A1	4/2020	Light et al.	
2020/0134175	A1	4/2020	Marwah et al.	
2020/0183655	A1	6/2020	Barday et al.	
2020/0186546	A1	6/2020	Dichiu et al.	
2020/0272763	A1	8/2020	Brannon et al.	
2020/0285737	A1	9/2020	Kraus et al.	
2020/0356689	A1	11/2020	McEnroe et al.	
2020/0356695	A1	11/2020	Brannon et al.	
2021/0019424	A1*	1/2021	Light	G06N 20/10
2021/0064746	A1	3/2021	Koide et al.	
2021/0073377	A1	3/2021	Coull et al.	
2021/0133331	A1*	5/2021	Lipkis	H04L 63/1483
2021/0266324	A1*	8/2021	Light	H04L 41/22
2021/0342785	A1	11/2021	Mann et al.	
2022/0191232	A1	6/2022	Cai et al.	
2023/0030077	A1	2/2023	Park et al.	

OTHER PUBLICATIONS

U.S. Appl. No. 15/377,574, U.S. Pat. No. 9,705,932, Methods and Systems for Creating, De-Duplicating, and Accessing Data Using an Object Storage System, filed Dec. 13, 2016.
U.S. Appl. No. 14/021,585 U.S. Pat. No. 9,438,615 Published as: US2015/0074579, Security Risk Management, filed Sep. 9, 2013.
U.S. Appl. No. 15/216,955 U.S. Pat. No. 10,326,786 Published as: US 2016/0330231, Methods for Using Organizational Behavior for Risk Ratings, filed Jul. 22, 2016.
U.S. Appl. No. 15/239,063 U.S. Pat. No. 10,341,370 Published as: US2017/0093901, Security Risk Management, filed Aug. 17, 2016.
U.S. Appl. No. 16/405,121 U.S. Pat. No. 10,785,245 Published as: US2019/0260791, Methods for Using Organizational Behavior for Risk Ratings, filed May 7, 2019.
U.S. Appl. No. 17/025,930 Published as: US2021/0006581, Methods for Using Organizational Behavior for Risk Ratings, filed Sep. 18, 2020.
U.S. Appl. No. 18/297,863, Methods for Using Organizational Behavior for Risk Ratings, filed Apr. 10, 2023.
U.S. Appl. No. 13/240,572 U.S. Pat. No. 10,805,331 Published as: US2016/0205126, Information Technology Security Assessment System, filed Sep. 22, 2011.
U.S. Appl. No. 14/944,484 U.S. Pat. No. 9,973,524 Published as: US2016/0323308, Information Technology Security Assessment System, filed Nov. 18, 2015.
U.S. Appl. No. 17/069,151 Published as: US2021/0211454, Information Technology Security Assessment System, filed Oct. 13, 2020.
U.S. Appl. No. 15/142,677 U.S. Pat. No. 9,830,569 Published as: US2016/0239772, Security Assessment Using Service Provider Digital Asset Information, filed Apr. 29, 2016.
U.S. Appl. No. 15/134,845 U.S. Pat. No. 9,680,858, Annotation Platform for a Security Risk System, filed Apr. 21, 2016.
U.S. Appl. No. 15/044,952 U.S. Pat. No. 11,182,720 Published as: US2017/0236077, Relationships Among Technology Assets and Services and the Entities Responsible for Them, filed Feb. 16, 2016.
U.S. Appl. No. 15/089,375 U.S. Pat. No. 10,176,445 Published as: US2017/0236079, Relationships Among Technology Assets and Services and the Entities Responsible for Them, filed Apr. 1, 2016.
U.S. Appl. No. 29/598,298 Des. 835,631, Computer Display Screen With Graphical User Interface, filed Mar. 24, 2017.
U.S. Appl. No. 29/598,299 Des. 818,475, Computer Display With Security Ratings Graphical User Interface, filed Mar. 24, 2017.
U.S. Appl. No. 29/599,622 Des. 847,169, Computer Display With Security Ratings Graphical User Interface, filed Apr. 5, 2017.
U.S. Appl. No. 29/599,620 Des. 846,562, Computer Display With Security Ratings Graphical User Interface, filed Apr. 5, 2017.
U.S. Appl. No. 16/015,686 U.S. Pat. No. 10,425,380 Published as: US2018/0375822, Methods for Mapping IP Addresses and Domains to Organizations Using User Activity Data, filed Jun. 22, 2018.
U.S. Appl. No. 16/543,075 U.S. Pat. No. 10,554,619 Published as: US2019/0379632, Methods for Mapping IP Addresses and Domains to Organizations Using User Activity Data, filed Aug. 16, 2019.
U.S. Appl. No. 16/738,825 U.S. Pat. No. 10,893,021 Published as: US2020/0153787, Methods for Mapping IP Addresses and Domains to Organizations Using User Activity Data, filed Jan. 9, 2020.
U.S. Appl. No. 17/146,064 Published as: US2021/0218702, Methods for Mapping IP Addresses and Domains to Organizations Using User Activity Data, filed Jan. 11, 2021.
U.S. Appl. No. 15/918,286 U.S. Pat. No. 10,257,219, Correlated Risk in Cybersecurity, filed Mar. 12, 2018.
U.S. Appl. No. 16/292,956 U.S. Pat. No. 10,594,723 Published as: US2019/0297106, Correlated Risk in Cybersecurity, filed Mar. 5, 2019.
U.S. Appl. No. 16/795,056 U.S. Pat. No. 10,931,705 Published as: US2020/0195681, Correlated Risk in Cybersecurity, filed Feb. 19, 2020.
U.S. Appl. No. 17/179,630 Published as US2021/0176269, Correlated Risk in Cybersecurity, filed Feb. 19, 2021.
U.S. Appl. No. 16/170,680 U.S. Pat. No. 10,521,583, Systems and Methods for Remote Detection of Software Through Browser Webinjects, filed Oct. 25, 2018.
U.S. Appl. No. 16/688,647 U.S. Pat. No. 10,776,483 Published as: US2020/0134174, Systems and Methods for Remote Detection of Software Through Browser Webinjects, filed Nov. 19, 2019.
U.S. Appl. No. 17/000,135 U.S. Pat. No. 11,126,723 Published as: US2021/0004457, Systems and Methods for Remote Detection of Software Through Browser Webinjects, filed Aug. 21, 2020.
U.S. Appl. No. 17/401,683 Published as: US2021/0374243, Systems and Methods for Remote Detection of Software Through Browser Webinjects, filed Aug. 13, 2021.
U.S. Appl. No. 15/954,921 U.S. Pat. No. 10,812,520 Published as: US2019/0319979, Systems and Methods for External Detection of Misconfigured Systems, filed Apr. 17, 2018.
U.S. Appl. No. 17/014,495 Published as: US2020/0404017, Systems and Methods for External Detection of Misconfigured Systems, filed Sep. 8, 2020.
U.S. Appl. No. 18/302,925, Systems and Methods for External Detection of Misconfigured Systems, filed Apr. 19, 2023.
U.S. Appl. No. 16/549,764 Published as: US2021/0058421, Systems and Methods for Inferring Entity Relationships via Network Communications of Users or User Devices, filed Aug. 23, 2019.
U.S. Appl. No. 16/787,650 U.S. Pat. No. 10,749,893, Systems and Methods for Inferring Entity Relationships via Network Communications of Users or User Devices, filed Feb. 11, 2020
U.S. Appl. No. 16/583,991 U.S. Pat. No. 10,848,382, Systems and Methods for Network Asset Discovery and Association Thereof With Entities, filed Sep. 26, 2019.
U.S. Appl. No. 17/085,550 U.S. Pat. No. 11,329,878 Published as: US2021/0099347, Systems and Methods for Network Asset Discovery and Association Thereof With Entities, filed Oct. 30, 2020.
U.S. Appl. No. 29/666,942 Des. 892,135, Computer Display With Graphical User Interface, filed Oct. 17, 2018.
U.S. Appl. No. 16/360,641 U.S. Pat. No. 11,200,323 Published as: US2020/0125734, Systems and Methods for Forecasting Cybersecurity Ratings Based on Event-Rate Scenarios, filed Mar. 21, 2019.
U.S. Appl. No. 17/523166 Published as: US2022/0121753, Systems and Methods for Forecasting Cybersecurity Ratings Based on Event-Rate Scenarios, filed Nov. 10, 2021.
U.S. Appl. No. 16/514,771 U.S. Pat. No. 10,726,136, Systems and Methods for Generating Security Improvement Plans for Entities, filed Jul. 17, 2019.
U.S. Appl. No. 16/922,673 U.S. Pat. No. 11,030,325 Published as: US2021/0019424, Systems and Methods for Generating Security Improvement Plans for Entities, filed Jul. 7, 2020.
U.S. Appl. No. 17/307,577 Published as: US2021/0211454, Systems and Methods for Generating Security Improvement Plans for Entities, filed May 4, 2021.
U.S. Appl. No. 18/138,803, Systems and Methods for Generating Security Improvement Plans for Entities, filed Apr. 25, 2023.

(56) **References Cited**

OTHER PUBLICATIONS

U.S. Appl. No. 29/677306 Des. 905,702, Computer Display Screen With Corporate Hierarchy Graphical User Interface, filed Jan. 18, 2019.

U.S. Appl. No. 16/775,840 U.S. Pat. No. 10,791,140, Systems and Methods for Assessing Cybersecurity State of Entities Based on Computer Network Characterization, filed Jan. 29, 2020.

U.S. Appl. No. 17/018,587 U.S. Pat. No. 11,050,779, Systems and Methods for Assessing Cybersecurity State of Entities Based on Computer Network Characterization, filed Sep. 11, 2020.

U.S. Appl. No. 17/346,970, Systems and Methods for Assessing Cybersecurity State of Entities Based on Computer Network Characterization, filed Jun. 14, 2021.

U.S. Appl. No. 16/779,437 U.S. Pat. No. 10,893,067 Published as: US2021/0243221, Systems and Methods for Rapidly Generating Security Ratings, filed Jan. 31, 2020.

U.S. Appl. No. 17/132,512 Published as: US2021/0243221, Systems and Methods for Rapidly Generating Security Ratings, filed Dec. 23, 2020.

U.S. Appl. No. 18/158,594, Systems and Methods for Rapidly Generating Security Ratings, filed Jan. 24, 2023.

U.S. Appl. No. 17/119,822 U.S. Pat. No. 11,122,073, Systems and Methods for Cybersecurity Risk Mitigation and Management, filed Dec. 11, 2020.

U.S. Appl. No. 29/815,855 US2021/0099347, Computer Display With a Graphical User Interface for Cybersecurity Risk Management, filed Nov. 17, 2021.

U.S. Appl. No. 17/392,521 Published as US 2022/0191232, Systems and Methods for Cybersecurity Risk Mitigation and Management, filed Aug. 3, 2021.

U.S. Appl. No. 18/141,654, Systems and Methods for Cybersecurity Risk Mitigation and Management, filed May 1, 2023.

U.S. Appl. No. 16/802,232 U.S. Pat. No. 10,764,298, Systems and Methods for Improving a Security Profile of an Entity Based on Peer Security Profiles, filed Feb. 26, 2020.

U.S. Appl. No. 16/942,452 U.S. Pat. No. 11,265,330 Published as: US2021/0266324, Systems and Methods for Improving a Security Profile of an Entity Based on Peer Security Profiles, filed Jul. 29, 2020.

U.S. Appl. No. 29/725724, Computer Display With Risk Vectors Graphical User Interface, filed Feb. 26, 2020.

U.S. Appl. No. 29/736,641 Des. 937,870, Computer Display With Peer Analytics Graphical User Interface, filed Jun. 2, 2020.

U.S. Appl. No. 17/039,675 U.S. Pat. No. 11,032,244 Published as: US2021/0099428, Systems and Methods for Determining Asset Importance in Security Risk Management, filed Sep. 30, 2020.

U.S. Appl. No. 17/320,997 Published as US 2021/0344647, Systems and Methods for Determining Asset Importance in Security Risk Management, filed May 14, 2021.

U.S. Appl. No. 16/884,607 U.S. Pat. No. 11,023,585, Systems and Methods for Managing Cybersecurity Alerts, filed May 27, 2020.

U.S. Appl. No. 17/236,594 Published as: US2021/0374246, Systems and Methods for Managing Cybersecurity Alerts, filed Apr. 21, 2021.

U.S. Appl. No. 17/710,168 Published as: US2022/0318400, Systems and Methods for Assessing Cybersecurity Risk in a Work From Home Environment, filed Mar. 31, 2022.

U.S. Appl. No. 17/945,337 Published as US2023/0091953, Systems and Methods for Precomputation of Digital Asset Inventories, filed Sep. 15, 2022.

U.S. Appl. No. 17/856,217 Published as: US2023/0004655, Systems and Methods for Accelerating Cybersecurity Assessments, filed Jul. 1, 2022.

"Agreed Upon Procedures," Version 4.0, BITS, The Financial Institution Shared Assessments Program, Assessment Guide, Sep. 2008, 56 pages.

"Amazon Mechanical Turk," accessed on the internet at https://www.mturk.com/, (Nov. 9, 2018), 7 pages.

"An Executive View of IT Governance," IT Governance Institute, 2009, 32 pages.

"Assessing Risk in Turbulent Times," A Workshop for Information Security Executives, Glassmeyter/McNamee Center for Digital Strategies, Tuck School of Business at Dartmouth, Institute for Information Infrastructure Protection, 2009, 17 pages.

"Assuring a Trusted and Resilient Information and Communications Infrastructure," Cyberspace Policy Review, May 2009, 76 pages.

"Computer Network Graph, http://www.opte.org," accessed on the internet at http://www.opte.org, (Nov. 9, 2018), 1 page.

"Creating Transparency with Palantir," accessed on the internet at https://www.youtube.com/watch?v=8cbGChfagUA; Jul. 5, 2012; 1 page.

"Master Security Criteria," Version 3.0, BITS Financial Services Security Laboratory, Oct. 2001, 47 pages.

"Neo4j (neo4j.com)," accessed on the internet at https://web.archive.org/web/20151220150341/http://neo4j.com:80/developer/guide-data-visualization/; Dec. 20, 2015; 1 page.

"Palantir Cyber: Uncovering malicious behavior at petabyte scale," accessed on the internet at https://www.youtube.com/watch?v=EhYezV06EE; Dec. 21, 2012; 1 page.

"Palantir.com," accessed on the internet at http://www.palantir.com/; Dec. 2015; 2 pages.

"Plugging the Right Holes," Lab Notes, MIT Lincoln Library, Posted Jul. 2008, retrieved Sep. 14, 2010 from http://www.II.miLedufpublicationsflabnotesfpluggingtherightho! . . . , 2 pages.

"Rapid7 Nexpose Vulnerability Scanner," accessed on the internet at https://web.archive.org/web/20170520082737/https://www.rapid7.com/products/nexpose/; May 20, 2017.

"Report on Controls Placed in Operation and Test of Operating Effectiveness," EasCorp, Jan. 1 through Dec. 31, 2008, prepared by Crowe Horwath, 58 pages.

"Shared Assessments: Getting Started," BITS, 2008, 4 pages.

"Tenable Nessus Network Vulnerability Scanner," accessed on the internet at https://www.tenable.com/products/nessus/nessus-professional, (Nov. 9, 2018), 13 pages.

"Twenty Critical Controls for Effective Cyber Defense: Consensus Audit," Version 2.3, Nov. 13, 2009, retrieved on Apr. 9, 2010 from http://www.sans.org/critical-security-controls/print.php., 52 pages.

2009 Data Breach Investigations Report, study conducted by Verizon Business RISK Team, 52 pages.

U.S. Appl. No. 13/240,572, as of Nov. 18, 2015, 45 pages.

Artz, Michael Lyle, "NetSPA: A Network Security Planning Architecture," Massachusetts Institute of Technology, May 24, 2002, 97 pages.

Azman, Mohamed et al. Wireless Daisy Chain and Tree Topology Networks for Smart Cities. 2019 IEEE International Conference on Electrical, Computer and Communication Technologies (ICECCT). https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=8869252 (Year: 2019).

Basinya, Evgeny A.; Yushmanov, Anton A. Development of a Comprehensive Security System. 2019 Dynamics of Systems, Mechanisms and Machines (Dynamics). https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=8944700 (Year: 2019).

Bhilare et al., "Protecting Intellectual Property and Sensitive Information in Academic Campuses from Trusted Insiders: Leveraging Active Directory", SIGUCC, Oct. 2009 (5 pages).

BitSight, "Cyber Security Myths Versus Reality: How Optimism Bias Contributes to Inaccurate Perceptions of Risk", Jun. 2015, Dimensional Research, pp. 1-9.

Borgatti, et al., "On Social Network Analysis in a Supply Chain Context," Journal of Supply Chain Management; 45(2): 5-22; Apr. 2009, 18 pages.

Boyer, Stephen, et al., Playing with Blocks: SCAP-Enable Higher-Level Analyses, MIT Lincoln Laboratory, 5th Annual IT Security Automation Conference, Oct. 26-29, 2009, 35 pages.

Browne, Niall, et al., "Shared Assessments Program AUP and SAS70 Frequently Asked Questions," BITS, 4 pages.

Buckshaw, Donald L., "Use of Decision Support Techniques for Information System Risk Management," submitted for publication in Wiley's Encyclopedia of Quantitative Risk Assessment in Jan. 2007, 11 pages.

Buehler, Kevin S., et al., "Running with risk," The Mckinsey Quarterly, No. 4, 2003, pp. 40-49.

Camelo, "Botnet Cluster Identification," Sep. 2014, 90 pages.

(56) References Cited

OTHER PUBLICATIONS

Camelo, "Condenser: A Graph-based Approach for Detecting Botnets," AnubisNetworks R&D, Amadora, Portugal and Centria, Universidade NOVA de Lisboa, Portugal, 8 pages, (Oct. 31, 2014).

Carstens, et al., "Modeling Company Risk and Importance in Supply Graphs," European Semantic Web Conference 2017: The Semantic Web, pp. 18-31, (May 7, 2017).

Chernyshev, M. et al., "On 802.11 Access Point Locatability and Named Entity Recognition in Service Set Identifiers", IEEE Trans. on Info. and Sec., vol. 11 No. 3 (Mar. 2016).

Chu, Matthew, et al., "Visualizing Attack Graphs, Reachability, and Trust Relationships with Navigator," MIT Lincoln Library, VizSEC '10, Ontario, Canada, Sep. 14, 2010, 12 pages.

Chuvakin, "SIEM: Moving beyond compliance", RSA White Paper (2010) (16 pages).

Computer Network Graph-Bees, http://bioteams.com/2007/04/30/visualizing_complex_networks.html, date accessed Sep. 28, 2016, 2 pages.

Computer Network Graph-Univ. of Michigan, http://people.cst.cmich.edu/liao1q/research.shtml, date accessed Sep. 28, 2016, 5 pages.

Crowther, Kenneth G., et al., "Principles for Better Information Security through More Accurate, Transparent Risk Scoring," Journal of Homeland Security and Emergency Management, vol. 7, Issue 1, Article 37, 2010, 20 pages.

Davis, Lois M., et al., "The National Computer Security Survey (NCSS) Final Methodology," Technical report prepared for the Bureau of Justice Statistics, Safety and Justice Program, RAND Infrastructure, Safety and Environment (ISE), 2008, 91 pages.

Dillon-Merrill, PhD., Robin L, et al., "Logic Trees: Fault, Success, Attack, Event, Probability, and Decision Trees," Wiley Handbook of Science and Technology for Homeland Security, 13 pages, (Mar. 15, 2009).

Dun & Bradstreet Corp. Stock Report, Standard & Poor's, Jun. 6, 2009, 8 pages.

Dun & Bradstreet, The DUNSRight Quality Process: Power Behind Quality Information, 24 pages.

Edmonds, Robert, "ISC Passive DNS Architecture", Internet Systems Consortium, Inc., Mar. 2012, 18 pages.

Equifax Inc. Stock Report, Standard & Poor's, Jun. 6, 2009, 8 pages.

Gephi (gephi.org), accessed on the internet at https://web.archive.org/web/20151216223216/https://gephi.org/; Dec. 16, 2015; 1 page.

Gilgur, et al., "Percentile-Based Approach to Forecasting Workload Growth" Proceedings of CMG'15 Performance and Capacity International Conference by the Computer Measurement Group. No. 2015 (Year:2015), 16 pages.

Gundert, Levi, "Big Data in Security—Part III: Graph Analytics," accessed on the Internet at https://blogs.cisco.com/security/big-data-in-security-part-iii-graph-analytics; Cisco Blog, Dec. 2013, 8 pages.

Hachem, Sara; Toninelli, Alessandra; Pathak, Animesh; Issany, Valerie. Policy-Based Access Control in Mobile Social Ecosystems. 2011 IEEE International Symposium on Policies for Distributed Systems and Networks (Policy). Http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=5976796. 8 pages, (Jun. 6, 2011).

Hacking Exposed 6, S. McClure et al., copyright 2009, 37 pages.

Ingols, Kyle, et al., "Modeling Modern Network Attacks and Countermeasures Using Attack Graphs," MIT Lincoln Laboratory, 16 pages, (Dec. 7, 2009).

Ingols, Kyle, et al., "Practical Attack Graph Generation for Network Defense," MIT Lincoln Library, IEEE Computer Society, Proceedings of the 22nd Annual Computer Security Applications Conference (ACSAC'06), 2006, 10 pages.

Ingols, Kyle, et al., "Practical Experiences Using SCAP to Aggregate CND Data," MIT Lincoln Library, Presentation to Nist Scap Conference, Sep. 24, 2008, 59 pages.

Jean, "Cyber Security: How to use graphs to do an attack analysis," accessed on the internet at https://linkurio.us/blog/cyber-security-use-graphs-attack-analysis/; Aug. 2014, 11 pages.

Jin et al., "Identifying and tracking suspicious activities through IP gray space analysis", MineNet, Jun. 12, 2007 (6 pages).

Johnson, Eric, et al., "Information Risk and the Evolution of the Security Rating Industry," Mar. 24, 2009, 27 pages.

Joslyn, et al., "Massive Scale Cyber Traffic Analysis: A Driver for Graph Database Research," Proceedings of the First International Workshop on Graph Data Management Experience and Systems (GRADES 2013), 6 pages.

KC Claffy, "Internet measurement and data analysis: topology, workload, performance and routing statistics," accessed on the Internet at http://www.caida.org/publications/papers/1999/Nae/Nae.html., NAE '99 workshop, 1999, 22 pages.

Li et al., "Finding the Linchpins of the Dark Web: a Study on Topologically Dedicated Hosts on Malicious Web Infrastructures", IEEE, 2013 (15 pages).

Lippmann, Rich, et al., NetSPA: a Network Security Planning Architecture, MIT Lincoln Laboratory, 11 pages.

Lippmann, Richard, et al., "Validating and Restoring Defense in Depth Using Attack Graphs," MIT Lincoln Laboratory, 10 pages, (Oct. 23, 2006).

Lippmann, RP., et al., "An Annotated Review of Papers on Attack Graphs," Project Report IA-1, Lincoln Laboratory, Massachusetts Institute of Technology, Mar. 31, 2005, 39 pages.

Lippmann, RP., et al., "Evaluating and Strengthening Enterprise Network Security Using Attack Graphs," Project Report IA-2, MIT Lincoln Laboratory, Oct. 5, 2005, 96 pages.

Luo, Hui; Henry, Paul. A Secure Public Wireless LAN Access Technique That Supports Walk-Up Users. GLOBECOM '03. IEEE Global Telecommunications Conference. https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber= 1258471 (Year: 2003).

Maltego XL, accessed on the Internet at https://www.paterva.com/web7/buy/maltego-clients/maltego-xl.php, 5 pages, (Nov. 7, 2018).

Massimo Candela, "Real-time BGP Visualisation with BGPlay," accessed on the Internet at https://labs.ripe.net/Members/massimo_candela/real-time-bgp-visualisationwith-bgplay), Sep. 30, 2015, 8 pages.

MaxMind, https://www.maxmind.com/en/about-maxmind, https://www.maxmind.com/en/geoip2-isp-database, date accessed Sep. 28, 2016, 3 pages.

McNab, "Network Security Assessment," copyright 2004, 13 pages.

McNab, "Network Security Assessment," copyright 2004, 56 pages.

Method Documentation, CNSS Risk Assessment Tool Version 1.1, Mar. 31, 2009, 24 pages.

Mile 2 CPTE Maltego Demo, accessed on the internet at https://www.youtube.com/watch?v=o2oNKOUzPOU; Jul. 12, 2012; 1 page.

Moradi, et al., "Quantitative Models for Supply Chain Management," IGI Global, 2012, 29 pages.

Morningstar Direct, dated to Nov. 12, 2020, morningstardirect.com [online]. Retrieved Feb. 26, 2021 from internet URL:https://web.archive.org/web/20201112021943/https://www.morningstar.com/products/direct, (Year: 2020).

Netcraft, www.netcraft.com, date accessed Sep. 28, 2016, 2 pages.

NetScanTools Pro, http://www.netscantools.com/nstpromain.html, date accessed Sep. 28, 2016, 2 pages.

Noel, et al., "Big-Data Architecture for Cyber Attack Graphs, Representing Security Relationships in NoSQL Graph Databases," The MITRE Corporation, 2014, 6 pages.

Nye, John, "Avoiding Audit Overlap," Moody's Risk Services, Presentation, Source Boston, Mar. 14, 2008, 19 pages.

U.S. Appl. No. 14/021,585, as of Apr. 29, 2016, 2 pages.

U.S. Appl. No. 14/021,585, as of Nov. 18, 2015, 6 pages.

U.S. Appl. No. 13/240,572 and pending claims as of Mar. 22, 2016, 10 pages.

U.S. Appl. No. 13/240,572, as of Oct. 7, 2015, application as filed and pending claims, 45 pages.

U.S. Appl. No. 14/021,585 and pending claims as of Mar. 22, 2016, 2 pages.

U.S. Appl. No. 14/021,585 as of Oct. 7, 2015 and application as filed, 70 pages.

U.S. Appl. No. 14/944,484 and pending claims as of Mar. 22, 2016, 4 pages.

U.S. Appl. No. 61/386,156 as of Oct. 7, 2015. 2 pages.

Application as filed and pending claims for U.S. Appl. No. 13/240,572 as of Apr. 29, 2016, 46 pages.

(56) **References Cited**

OTHER PUBLICATIONS

Application as filed and pending claims for U.S. Appl. No. 14/944,484 as of Apr. 29, 2016, 4 pages.

Paxson, Vern, "How The Pursuit of Truth Led Me tSelling Viagra," EECS Department, University of California, International Computer Science Institute, Lawrence Berkeley National Laboratory, Aug. 13, 2009, 68 pages.

Proposal and Award Policies and Procedures Guide, Part I—Proposal Preparation & Submission Guidelines GPG, The National Science Foundation, Feb. 2009, 68 pages.

Provos et al., "The Ghost In the Browser Analysis of Web-based Malware", 2007 (9 pages).

Rare Events, Oct. 2009, JASON, The MITRE Corporation, Oct. 2009, 104 pages.

Rees, L. P. et al., "Decision support for cybersecurity risk planning." Decision Support Systems 51.3 (2011): pp. 493-505.

Report to the Congress on Credit Scoring and Its Effects on the Availability and Affordability of Credit, Board of Governors of the Federal Reserve System, Aug. 2007, 304 pages.

RFC 1834, https://tools.ietf.org/html/rfc1834, date accessed Sep. 28, 2016, 7 pages.

RFC 781, https://tools.ietf.org/html/rfc781, date accessed Sep. 28, 2016, 3 pages.

RFC 950, https://tools.ietf.org/html/rfc950, date accessed Sep. 28, 2016, 19 pages.

RFC 954, https://tools.ietf.org/html/rfc954, date accessed Sep. 28, 2016, 5 pages.

SamSpade Network Inquiry Utility, https://www.sans.org/reading-room/whitepapers/tools/sam-spade-934, date accessed Sep. 28, 2016, 19 pages.

Santos, J. R. et al., "A framework for linking cybersecurity metrics to the modeling of macroeconomic interdependencies." Risk Analysis: An International Journal (2007) 27.5, pp. 1283-1297.

SBIR Phase I: Enterprise Cyber Security Scoring, CyberAnalytix, LLC, http://www.nsf.gov/awardsearch/showAward. do?AwardNumber=I013603, Apr. 28, 2010, 2 pages.

Search Query Report from IP.com (performed Apr. 27, 2020).

Search Query Report from IP.com (performed Jul. 29, 2022).

Security Warrior, Cyrus Peikari, Anton, Chapter 8: Reconnaissance, 6 pages, (Jan. 2004).

Seigneur et al., A Survey of Trust and Risk Metrics for a BYOD Mobile Worker World: Third International Conference on Social Eco-Informatics, 2013, 11 pages.

Seneviratne et al., "SSIDs in the Wild: Extracting Semantic Information from WiFi SSIDs" HAL archives-ouvertes.fr, HAL Id: hal-01181254, Jul. 29, 2015, 5 pages.

Snort Intrusion Monitoring System, http://archive.oreilly.com/pub/h/1393, date accessed Sep. 28, 2016, 3 pages.

Srivastava, Divesh; Velegrakis, Yannis. Using Queries to Associate Metadata with Data. IEEE 23rd International Conference on Data Engineering. Pub. Date: 2007. http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=4221823, 3 pages.

Stone-Gross, Brett, et al., "FIRE: Finding Rogue Networks," 10 pages, (Dec. 7, 2009).

Taleb, Nassim N., et al., "The Six Mistakes Executives Make in Risk Management," Harvard Business Review, Oct. 2009, 5 pages.

The CIS Security Metrics vl.0.0, The Center for Internet Security, May 11, 2009, 90 pages.

The Fair Credit Reporting Act (FCRA) of the Federal Trade Commission (FTC), Jul. 30, 2004, 86 pages.

The Financial Institution Shared Assessments Program, Industry Positioning and Mapping Document, BITS, Oct. 2007, 44 pages.

Wagner, et al., "Assessing the vulnerability of supply chains using graph theory," Int. J. Production Economics 126 (2010) 121-129.

Wikipedia, https://en.wikipedia.org/wiki/Crowdsourcing, date accessed Sep. 28, 2016, 25 pages.

Williams, Leevar, et al., "An Interactive Attack Graph Cascade and Reachability Display," MIT Lincoln Laboratory, 17 pages, (Jan. 2007).

Williams, Leevar, et al., "GARNET: A Graphical Attack Graph and Reachability Network Evaluation Tool," MIT Lincoln Library, VizSEC 2009, pp. 44-59, (Sep. 15, 2008).

Winship, C., "Models for sample selection bias", Annual review of sociology, 18(1) (Aug. 1992), pp. 327-350.

"Maltego 3 GUI user guide," 11 pages, Nov. 22, 2010 retrieved from Internet Archive Wayback Machine, https://web.archive.org/web/20101122112311/http://www.paterva.com:80/web5/documentation/Maltego3_crash_course.pdf on Aug. 30, 2024.

"User guide—Addendum to guide for Maltego 3.0.2," 20 pages, Nov. 23, 2010 retrieved from Internet Archive Wayback Machine, https://web.archive.org/web/20101123012539/http://www.paterva.com:80/web5/documentation/3.0.2.addendum.pdf on Aug. 30, 2024.

'834 Patent Claim Chart, *BitSight Technologies, Inc.* v. *NormShield Inc.* d/b/a Black Kite Inc., Case No. 1:23-cv-12055-MJJ, D.I. 39-11 (Dec. 11, 2023), 28 pages.

"Maltego User Guide" webpage http://ctas.paterva.com/view/Userguide, 35 pages, Jun. 6, 2012, retrieved from Internet Archive Wayback Machine https://web.archive.org/web/20120606172056/http://ctas.paterva.com/view/Userguide on Sep. 6, 2024.

"MW Metadata", webpage https://mattw.io/youtube-metadata, 7 pages, retrieved on Aug. 21, 2024.

Anderson, H., "Nessus, Part 3: Analysing Reports," webpage http://www.securityfocus.com/infocus/1759, 5 pages, Oct. 20, 2006, retrieved from Internet Archive Wayback Machine https://web.archive.org/web/20061020202310/http://www.securityfocus.com/infocus/1759 on Aug. 16, 2024.

Aug. 29, 2024 Email from Melissa Nezhnik, 3 pages.

Curriculum Vitae of Kevin Almeroth Ph.D., 40 pages.

Declaration of Dr. Kevin Almeroth, 109 pages.

Declaration of Dr. Kevin Almeroth, 95 pages.

Declaration of Kevin Almeroth, Ph.D., 127 pages.

Declaration of Kevin Almeroth, Ph.D., 131 pages.

Declaration of Kevin C. Almeroth, PH.D. in support of Petition for Inter Partes Review of U.S. Pat. No. 11,777,976, 79 pages.

Declaration of Nathaniel Frank-White, 50 pages.

Declaration of Nathaniel Frank-White, 52 pages.

Declaration of Sylvia Hall-Ellis, Ph.D., 548 pages.

Gates, C., "New School Information Gathering," (2008), available at https://www.carnalOwnage.com/papers/17_Gates.pdf, 84 pages.

Gates, C., "Toorcon X Gates: New School Information Gathering," 2 pages, Mar. 2, 2009, retrieved from Internet Archive Wayback Machine https://web.archive.org/web/20090302045813/vimeo.com//2745624 on Aug. 13, 2024.

Gates, C., "Toorcon X Gates: New School Information Gathering," available at http://vimeo.com/2745624, 2 pages, retrieved on Aug. 13, 2024.

Khalil, J. et al., "Discovering Malicious Domains through Passive DNS Data Graph Analysis," Conference Paper, (Jun. 2016), 13 pages.

Knowles, D. et al., "W32.Blaster. Worm: Technical Details" webpage http://www.symantec.com/security_response/writeup.jsp?docid=2003- 081113-0229-99&tabid=2, 3 pages, May 3, 2007, retrieved from Internet Archive Wayback Machine https://web.archive.org/web/20070503023514/http://www.symantec.com/security_response/writeup.jsp?docid=2003-081113-0229-99&tabid=2 on Aug. 16, 2024.

Levy, E., "The Making of a Spam Zombie Army," IEEE Computer & Security (2003), pp. 58-59.

Long, J., "Google Hacking for Penetration Testers," 170 pages, Jan. 31, 2006, retrieved from Internet Archive Wayback Machine, https://web.archive.org/web/20060131095431/http://www.blackhat.com/presentations/bh-europe-05/BH_EU_05-Long.pdf on Aug. 30, 2024.

Martorella, C., "A fresh new look into Information Gathering," 68 pages, Dec. 29, 2009 retrieved from Internet Archive Wayback Machine, https://web.archive.org/web/20091229020339/http://www.edgesecurity.com/docs/OWASP-Christian_Martorella-InformationGathering.pdf on Aug. 30, 2024.

Matta Security Limited, "An Introduction to Internet Attack & Penetration," available at http:/www.trustmatta.com/downloads/pdf/, Matta_Attack_and_Penetration_Introduction.pdf, (2001-2002), 14 pages.

McNab, C., "Network Security Assessment," O'Reilly Media, Inc., Second Edition, (2008), 506 pages.

(56) **References Cited**

OTHER PUBLICATIONS

Moore & Valsmith, et al., "Tactical Exploitation," 37 pages, Feb. 8, 2010, retrieved from Internet Archive Wayback Machine https://web.archive.org/web/20100208161237/https:/www.blackhat.com/presentations/bh-usa-07/Moore_and_Valsmith/Whitepaper/bh-usa-07-moore_and_valsmith-WP.pdf.

Nessus, "Documentation," webpage http://www.nessus.org/documentation/, 2 pages, Feb. 19, 2007, retrieved from Internet Archive Wayback Machine https://web.archive.org/web/20070219213924/http://www.nessus.org/documentation/ on Aug. 16, 2024.

Nessus, "Plugins: Symantec Anti Virus Corporate Edition Check," webpage http://www.nessus.org/plugins/index.php?view=single&id=21725, 2 pages, Feb. 22, 2007, retrieved from Internet Archive Wayback Machine https://web.archive.org/web/20070222133717/http://www.nessus.org/plugins/index.php?view=single&id=21725 on Aug. 13, 2024.

Nessus, "Plugins: The remote host is infected by a virus", webpage http://www.nessus.org/plugins/index.php?view=single&id=11329, 2 pages, Feb. 22, 2007, retrieved from Internet Archive Wayback Machine https://web.archive.org/web/20070222091638/http://www.nessus.org/plugins/index.php?view=single&id=11329 on Aug. 13, 2024.

Nessus, "Plugins: The remote host is infected by msblast.exe", webpage http://www.nessus.org/plugins/index.php?view=single&id=11818, 1 page, Sep. 24, 2006, retrieved from Internet Archive Wayback Machine https://web.archive.org/web/20060924205758/http://www.nessus.org/plugins/index.php?view=single&id=11818 on Aug. 13, 2024.

Prosecution History for U.S. Pat. No. 10,805,331, 1060 pages.

Prosecution History for U.S. Pat. No. 11,652,834, 344 pages.

Prosecution History for U.S. Pat. No. 11,777,976, 651 pages.

Prosecution History for U.S. Pat. No. 9,438,615, 232 pages.

Prosecution History for U.S. Pat. No. 9,973,524, 424 pages.

Representative Sample. Julie Young, Investopedia. Published Apr. 10, 2019 (Web Archive Aug. 19, 2019). Accessed on Aug. 19, 2024. [https://web.archive.org/web/20190819095403/https://www.investopedia.com/terms/r/representative-sample.asp].

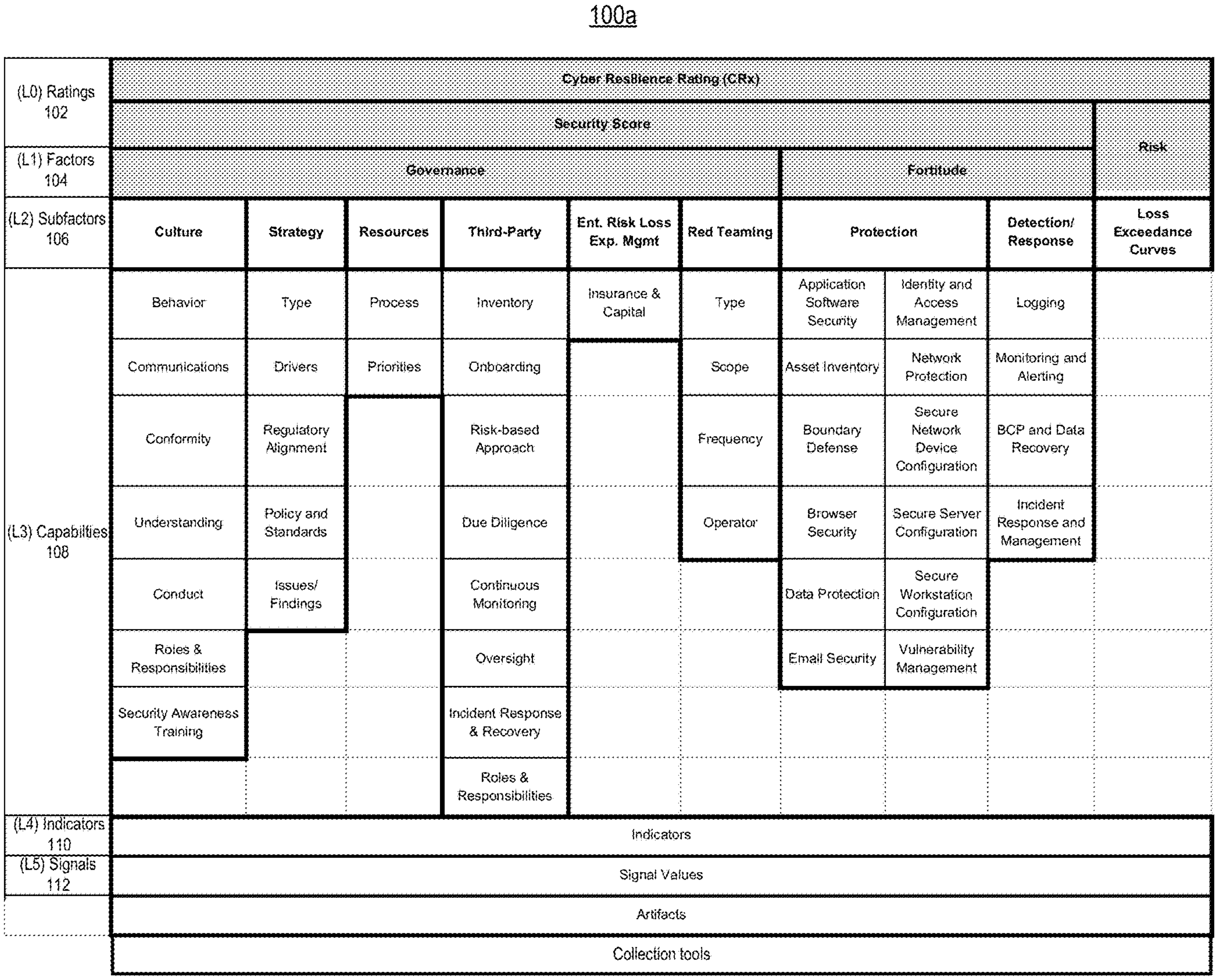
Social-Engineer, LLC, "Social Engineering Using Maltego," webpage <www.youtube.com/watch?v=qiv4-wy3mxo>, 2 pages, Sep. 14, 2009, retrieved on Aug. 13, 2024.

Social-Engineer, LLC, Screen captures from "Social Engineering Using Maltego," webpage <www.youtube.com/watch?v=qiv4-wy3mxo>, 43 pages, Sep. 14, 2009.

Stoneburner, G. et al., "Risk Management Guide for Information Technology Systems," NIST, available at https://www.archives.gov/files/era/recompete/sp800-30.pdf, (Jul. 2002), 55 pages.

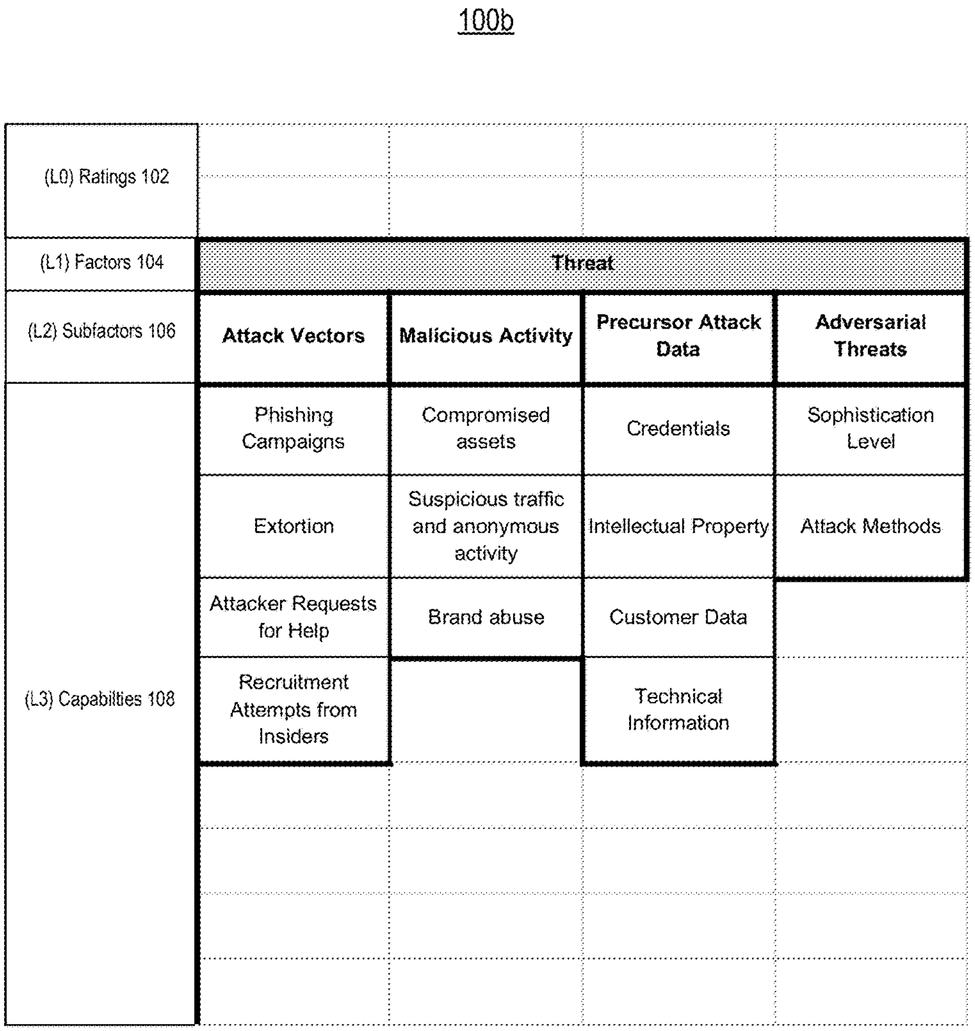
Tenable Network Security, Inc., "Nessus 3.0 Client Guide," available at http://nessus.org/documentation/nessus_3.0_client_guide.pdf, Mar. 6, 2007, 32 pages.

* cited by examiner



(L0) Ratings 102	Cyber Resilience Rating (CRx)									
	Security Score									Risk
(L1) Factors 104	Governance						Fortitude			
(L2) Subfactors 106	**Culture**	**Strategy**	**Resources**	**Third-Party**	**Ent. Risk Loss Exp. Mgmt**	**Red Teaming**	**Protection**		**Detection/ Response**	**Loss Exceedance Curves**
(L3) Capabilities 108	Behavior	Type	Process	Inventory	Insurance & Capital	Type	Application Software Security	Identity and Access Management	Logging	
	Communications	Drivers	Priorities	Onboarding		Scope	Asset Inventory	Network Protection	Monitoring and Alerting	
	Conformity	Regulatory Alignment		Risk-based Approach		Frequency	Boundary Defense	Secure Network Device Configuration	BCP and Data Recovery	
	Understanding	Policy and Standards		Due Diligence		Operator	Browser Security	Secure Server Configuration	Incident Response and Management	
	Conduct	Issues/ Findings		Continuous Monitoring			Data Protection	Secure Workstation Configuration		
	Roles & Responsibilities			Oversight			Email Security	Vulnerability Management		
	Security Awareness Training			Incident Response & Recovery						
				Roles & Responsibilities						
(L4) Indicators 110	Indicators									
(L5) Signals 112	Signal Values									
	Artifacts									
	Collection tools									

FIG. 1A



(L0) Ratings 102				
(L1) Factors 104	Threat			
(L2) Subfactors 106	**Attack Vectors**	**Malicious Activity**	**Precursor Attack Data**	**Adversarial Threats**
(L3) Capabilties 108	Phishing Campaigns	Compromised assets	Credentials	Sophistication Level
	Extortion	Suspicious traffic and anonymous activity	Intellectual Property	Attack Methods
	Attacker Requests for Help	Brand abuse	Customer Data	
	Recruitment Attempts from Insiders		Technical Information	

FIG. 1B

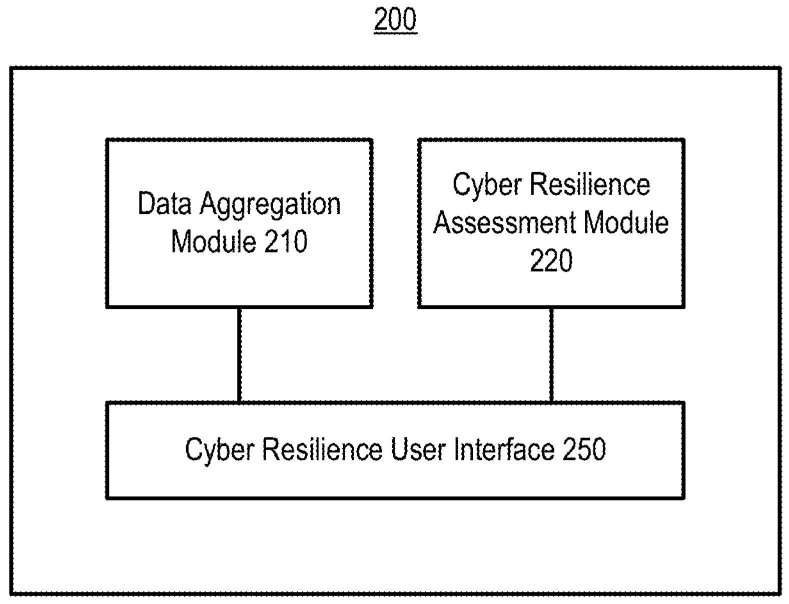

200
Data Aggregation Module 210
Cyber Resilience Assessment Module 220
Cyber Resilience User Interface 250

FIG. 2

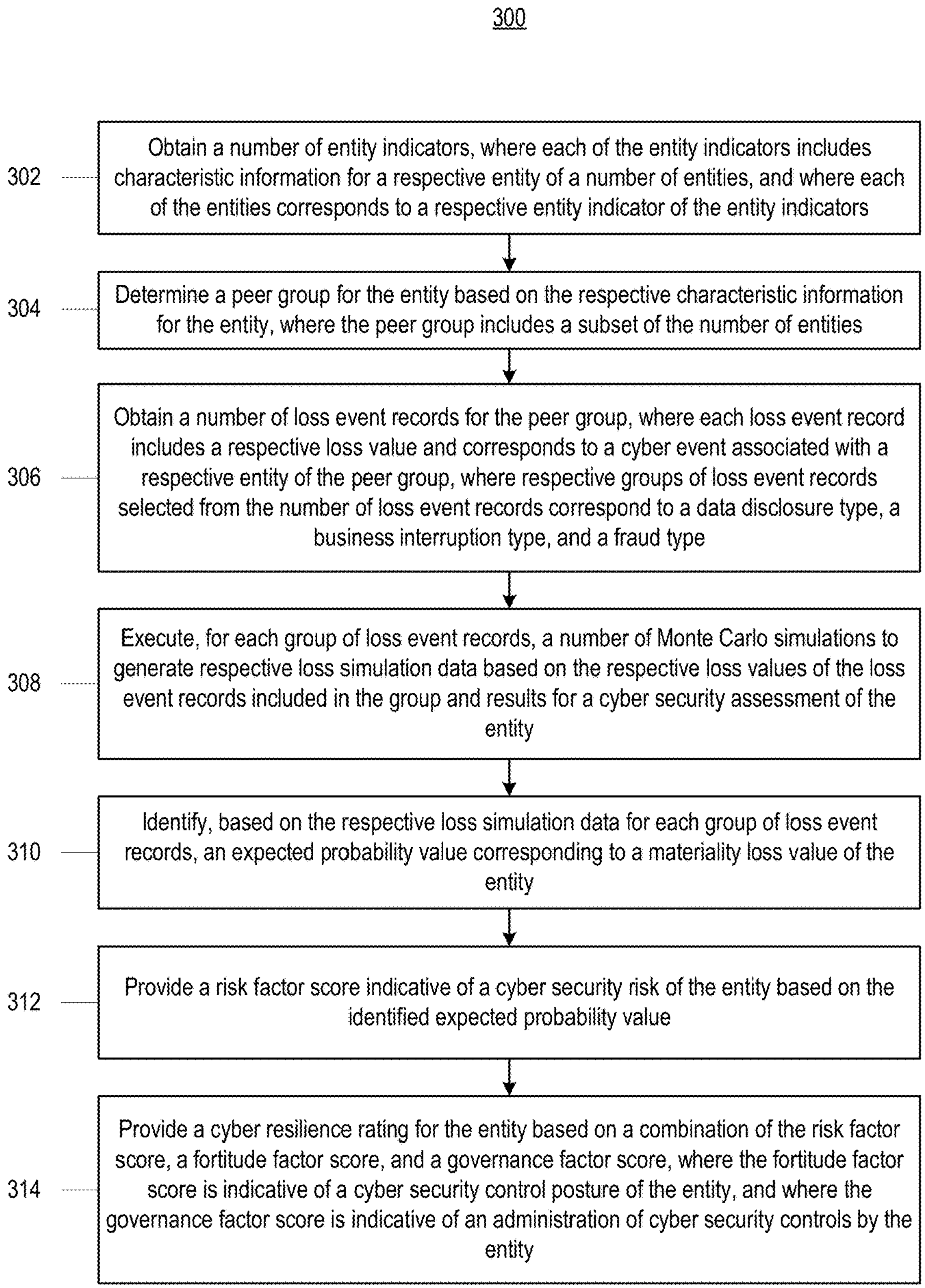

300
302
Obtain a number of entity indicators, where each of the entity indicators includes characteristic information for a respective entity of a number of entities, and where each of the entities corresponds to a respective entity indicator of the entity indicators
304
Determine a peer group for the entity based on the respective characteristic information for the entity, where the peer group includes a subset of the number of entities
306
Obtain a number of loss event records for the peer group, where each loss event record includes a respective loss value and corresponds to a cyber event associated with a respective entity of the peer group, where respective groups of loss event records selected from the number of loss event records correspond to a data disclosure type, a business interruption type, and a fraud type
308
Execute, for each group of loss event records, a number of Monte Carlo simulations to generate respective loss simulation data based on the respective loss values of the loss event records included in the group and results for a cyber security assessment of the entity
310
Identify, based on the respective loss simulation data for each group of loss event records, an expected probability value corresponding to a materiality loss value of the entity
312
Provide a risk factor score indicative of a cyber security risk of the entity based on the identified expected probability value
314
Provide a cyber resilience rating for the entity based on a combination of the risk factor score, a fortitude factor score, and a governance factor score, where the fortitude factor score is indicative of a cyber security control posture of the entity, and where the governance factor score is indicative of an administration of cyber security controls by the entity

FIG. 3

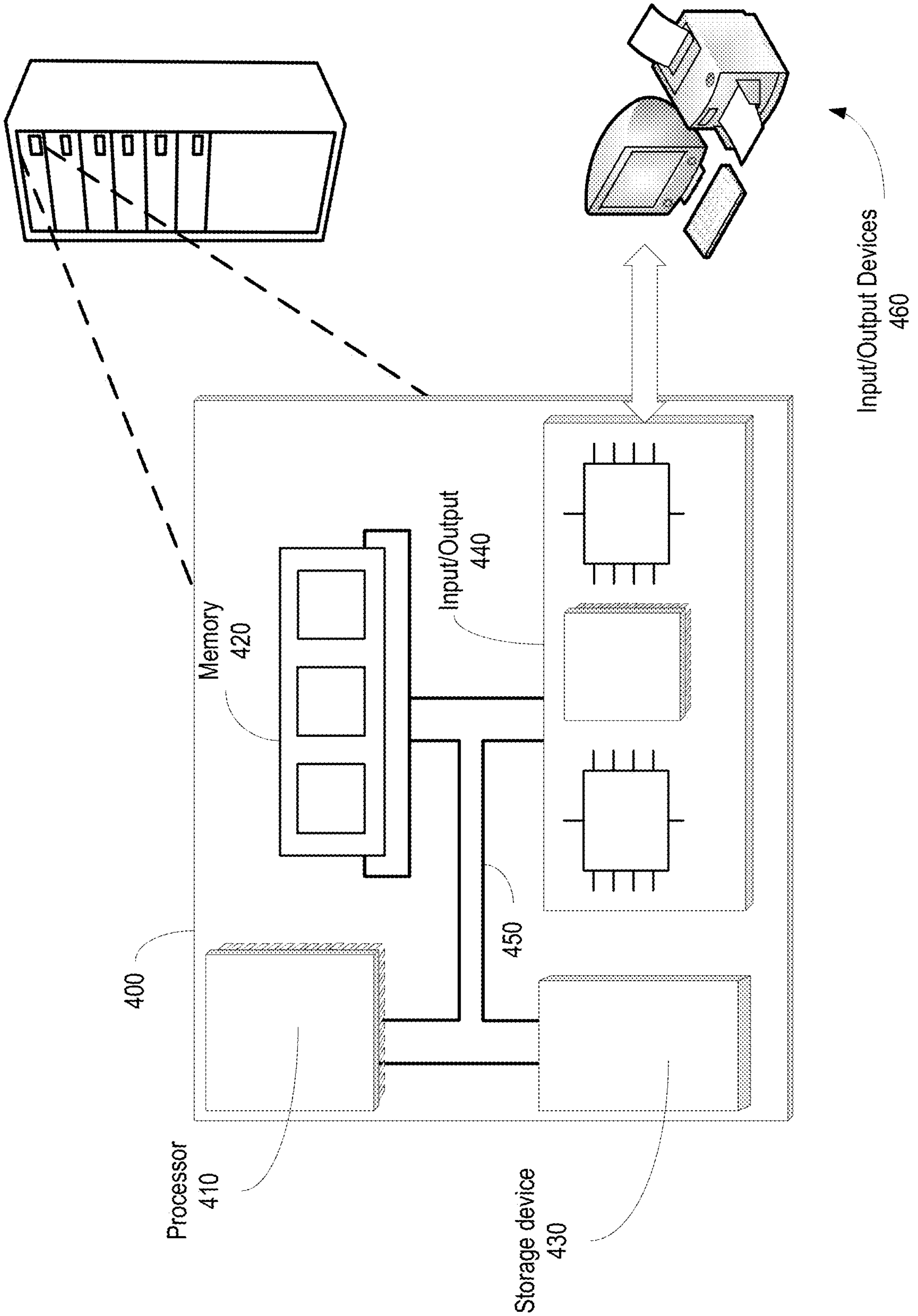

400
Processor
410
Memory
420
Storage device
430
Input/Output
440
450
Input/Output Devices
460

FIG. 4

SYSTEMS AND METHODS FOR ASSESSMENT OF CYBER RESILIENCE

CROSS-REFERENCE TO RELATED APPLICATION(S)

This application claims the benefit of and priority to U.S. Provisional Application No. 63/305,082, filed on Jan. 31, 2022, entitled "SYSTEMS AND METHODS FOR ASSESSMENT OF CYBER RESILIENCE," which is hereby incorporated by reference herein in its entirety.

TECHNICAL FIELD

The following disclosure is directed to methods and systems for cybersecurity assessment, more specifically, methods and systems for assessment of cyber resilience for an entity and for affiliates having relationships with the entity.

BACKGROUND

Assessment of cybersecurity states of businesses, corporations, organizations, and other 'entities' can involve identifying and monitoring risks (e.g., threats) impacting cyber assets corresponding to each of the respective entities. Further, entities often outsource tasks to third parties. As a result, such entities have relationships with (e.g., are 'related to' or 'connected to') numerous third party affiliates (i.e., vendors). An entity's cyber assets and the entity's relationships can thus leave the entity vulnerable to risks, which can be difficult to monitor and evaluate across multiple axes of measurement. Accordingly, entities may desire methods and systems for evaluating their cybersecurity, threat profile, policies and procedures for controlling cyber assets, and mitigation capabilities.

SUMMARY

This methods and systems described herein provide an approach for assessing an entity's cyber resilience across various axes of measurement. Cyber resilience as described herein may generally refer to the current cyber security state of an entity, the entity's threat profile, the policies and procedures for controlling cyber assets controlled and/or managed by the entity, and mitigation capabilities for mitigating and minimizing risk impacts. For example, an entity's cyber resilience can be quantified as an amount of threat activity the entity faces, which may also be measured relative to an entity's industry and peer entity group(s), the effectiveness of the entity's security controls and posture, the existence and effectiveness of the entity's security governance processes, and/or a risk magnitude and frequency of expected losses based on a combination of the previous factors. These factors may be used to assess one or more entities (including "affiliated entities" or "affiliates"), resulting in an accurate and measurable analysis of the cyber resilience of the entities. These factors may also be used as inputs to further analyze cyber risk across various use cases such as credit analysis, insurance underwriting, or the cyber impact of mergers and acquisitions, amongst others. The factors can be expressed as a single indicator (e.g., value) for purposes of benchmarking in order to establish a data set for comparative analysis between entities. Based on the value of these summary indicators potentially changing as a corpus of assessed entities grows, several different summary scoring options may be used.

The assessment methodology described herein may be deployed as a stand-alone assessment of critical aspects of an entity's overall cyber security posture or, in some cases, combined with other assessments. The assessment methodology may be used to inform organizational leadership, financial intermediaries, investors, partners, and other interested parties of an entity's cybersecurity profile and capabilities. The methodological results may be temporal, as the nature of cybersecurity threats and control posture can vary over time. As such, the value and confidence in the assessment results may diminish over time, in which case periodic (e.g., monthly, quarterly) updates are recommended in the intervening period prior to a re-issuance (e.g., annual re-issuance) of the assessment results in order to account for any changes that may have occurred over time.

Some of the assessment measures described herein may be absolute, based in part on best practices and activities positively correlated with good security, and other measures may be scored in a relative fashion compared to a cohort of peer scores. As a result, the goal for some entities may not be to achieve the highest score in each category, even though such a score may be possible. Industry-specific benchmarking can help guide entities to the individual selection of the most appropriate and/or efficient goals.

In one aspect, the subject matter described herein relates to a computer-implemented method for providing a cyber resilience rating for an entity of a plurality of entities. the method can include obtaining a plurality of entity indicators corresponding to the plurality of entities, wherein each of the plurality of entity indicators include characteristic information for a respective entity of the plurality of entities, and wherein each of the plurality of entities correspond to a respective entity indicator of the plurality of entity indicators. The method can include determining a peer group for the entity based on the respective characteristic information for the entity, wherein the peer group includes a subset of the plurality of entities. The method can include obtaining a plurality of loss event records for the peer group, wherein each loss event record includes a respective loss value and corresponds to a cyber event associated with a respective entity of the peer group, wherein respective groups of loss event records selected from the plurality of loss event records correspond to a data disclosure type, a business interruption type, and a fraud type. The method can include executing, for each group of loss event records, a plurality of Monte Carlo simulations to generate respective loss simulation data based on the respective loss values of the loss event records included in the group and results for a cyber security assessment of the entity. The method can include identifying, based on the respective loss simulation data for each group of loss event records, an expected probability value corresponding to a materiality loss value of the entity. The method can include providing a risk factor score indicative of a cyber security risk of the entity based on the identified expected probability value. The method can include providing a cyber resilience rating for the entity based on a combination of the risk factor score, a fortitude factor score, and a governance factor score, wherein the fortitude factor score is indicative of a cyber security control posture of the entity, and wherein the governance factor score is indicative of an administration of cyber security controls by the entity.

Various embodiments of the method can include one or more of the following features. The characteristic information can include an industry indicator, geography indicator, and size indicator for the respective entity. Determining the peer group for the entity based on the respective entity characteristics of the entity can further include: selecting, from the plurality of entities, a subset of the plurality of entities for inclusion in the peer group based on the respective characteristic information corresponding to each entity of the subset of the plurality of entities including at least one of: the industry indicator, geography indicator, and size indicator corresponding to the entity. The peer group can include a first peer group and a second peer group, wherein the first peer group and the second peer group comprise different subsets of the plurality of entities. Each loss event record of the plurality of loss event records can include a respective loss event type corresponding to one of: the data disclosure type, the business interruption type, or the fraud type. The method can further include selecting the respective groups of loss event records from the plurality of loss event records based on the respective loss event type of each loss event record included in the respective groups of loss event records. The data disclosure type can correspond to at least one of: a data breach; a data theft; a data loss; and an unintentional data disclosure. The business interruption type can correspond to at least one of: a cyber extortion event; a network disruption; and a website disruption. The fraud type can correspond to at least one of: an identity fraud event; a phishing event; and a skimming event.

Executing, for each group of loss event records, the plurality of Monte Carlo simulations to generate the respective loss simulation data can include: determining a statistic from the respective loss values of the loss event records included in the group; weighting the statistic based on the results for the cyber security assessment of the entity to determine a weighted statistics; and executing the plurality of Monte Carlo simulations based on the weighted statistic. The cyber security assessment can include an outside-in cyber security assessment or an inside-out cyber security assessment. The materiality loss value can be based on an industry indicator corresponding to the entity and a revenue corresponding to the entity. The method can further include determining a respective materiality ratio for each respective loss simulation data, wherein the each of the respective materiality ratios are based on the loss materiality value corresponding to the entity; and selecting the respective loss simulation data corresponding to a largest materiality ratio of the materiality ratios. Identifying the expected probability value corresponding to the materiality loss value of the entity can include: generating a loss exceedance curve indicative of a probability of loss potential for the entity based on the selected loss simulation data; and identifying, from the loss exceedance curve, the expected probability value corresponding to the materiality loss value of the entity. The method can further include: obtaining signal data indicative of a cyber resilience of the entity; generating, based on a first subset of the signal data, the fortitude factor score, wherein the first subset of the signal data is indicative of the cyber security control posture of the entity; and generating, based on a second subset of the signal data, the governance factor score, wherein the second subset of the signal data is indicative of the administration of cyber security controls by the entity.

Other aspects of the invention comprise systems implemented in various combinations of computing hardware and software to achieve the methods described herein.

The above and other preferred features, including various novel details of implementation and combination of events, will now be more particularly described with reference to the accompanying figures and pointed out in the claims. It will be understood that the particular systems and methods described herein are shown by way of illustration only and not as limitations. As will be understood by those skilled in the art, the principles and features described herein may be employed in various and numerous embodiments without departing from the scope of any of the present inventions. As can be appreciated from the foregoing and the following description, each and every feature described herein, and each and every combination of two or more such features, is included within the scope of the present disclosure provided that the features included in such a combination are not mutually inconsistent. In addition, any feature or combination of features may be specifically excluded from any embodiment of any of the present inventions.

The foregoing Summary, including the description of some embodiments, motivations therefor, and/or advantages thereof, is intended to assist the reader in understanding the present disclosure, and does not in any way limit the scope of any of the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings, like reference characters generally refer to the same parts throughout the different views. Also, the drawings are not necessarily to scale, emphasis instead generally being placed upon illustrating the principles of the invention. In the following description, various embodiments of the present invention are described with reference to the following drawings, in which:

FIG. **1**A depicts an exemplary diagram of a hierarchical model for cyber resilience assessment, according to some embodiments;

FIG. **1**B depicts an exemplary diagram of a hierarchical model for cyber resilience assessment, according to some embodiments;

FIG. **2** depicts a block diagram of a cybersecurity resilience assessment system, according to some embodiments;

FIG. **3** depicts a flowchart of an exemplary method for providing a cyber resilience rating for an entity, according to some embodiments; and

FIG. **4** is a block diagram of an example computer system that may be used in implementing the technology described herein.

DETAILED DESCRIPTION

The present disclosure is directed to methods and systems for cybersecurity assessment, more specifically, methods and systems for assessment of cyber resilience for an entity and for affiliates having relationships with the entity. The assessment methodology for assessment of cyber resilience may be based on one or more factors, including (i) an entity's threat profile (referred to a "threat" factor), control posture (referred to as a "fortitude" factor), security oversight (referred to as a "governance" factor), and a degree to which an assessed entity can adequately mitigate cyber events to reduce the financial impact if and when such events were to occur (referred to as a "risk" factor). Cyber events as described herein may also be referred to as "cyber loss events" and/or "loss events".

The fortitude and governance factors as described herein can indicate the extent to which an entity can improve its ability to prevent cyber events and mitigate impact corresponding to the cyber events. Indicators (e.g., ratings or scores) of the fortitude and governance factors, combined with an indicator of an assessed ability to manage recovery in response to a cyber event (e.g., attack) as a result of investments in security incident and crisis response, third-party oversight, and culture, can form a "cyber security score" (also referred to as a "cyber security rating"). These security control and governance activities can result in reductions in potential frequency and losses (e.g., financial losses) as indicated by the risk factor. In addition, an entity's threat profile may be measured based on a variety of factors, such as the entity's business profile and actual targeting by threats based on obtained threat intelligence data. Assessments of the fortitude, governance, and risk factors can be combined and summarized into an individual quantitative output indicator referred to herein as a "cyber resilience rating" or "CRx". In some cases, rating scales for the cyber resilience rating can require a minimum number of participating entities to enable sufficient historical analysis.

of cybersecurity threats to an entity, and constitute specific implementations of solutions to problems that arise when attempting to monitor and mitigate the cybersecurity risks faced by an entity. Thus, the improved cybersecurity assessment and mitigation techniques described herein constitute improvements to computer-related technology for reasons similar to those articulated by the Federal Circuit in Finjan, Inc. v. Blue Coat Systems, Inc. (Fed. Cir. 2018), among other reasons, and are not abstract ideas.

In some embodiments, the assessment methodology used by the methods and system described herein may be based on the terminology as described in Table 1.

TABLE 1

Terminology for Assessment Methodology	
Threat factor	Indicates a current state of threat activity facing an entity Examples of threat activity includes active attempts and plots found in underground forums where cyber criminals converge and evidence of Nation State attacks
Governance factor	Indicates an entity's oversight and administration of cyber security protocols and practices Examples of subfactors of governance include budgeting, resource management, strategy, and culture
Fortitude factor	Indicates an ability of an entity to present a strong security posture to the entity's threat communities, including measures of an entity's defensive capabilities and ability to remain resilient when the entity is unable to thwart an attack. The fortitude factor can include an evaluation of an entity's computing (e.g., cloud) infrastructure and visibility of the affiliates of the entity (e.g., the entity's supply chain)
Risk factor	Indicates the materiality of an event corresponding to an extreme or worse-case cyber incident.
Cyber Resilience Rating	Refers to an quantitative output indicative of an entity's cyber resilience The quantitative output may be based on the entirety of the various assessments described herein, examples of which are described with respect to "Exemplary Scoring for a Cyber Resilience Rating"
Posture	Refers to a measure of attack surface management and a state of an entity's cyber asset over a period of time
Exposure	Refers to a potential (e.g., probability) that an entity's asset(s) have vulnerabilities at a given time
Loss Exposure	Refers to a potential economic (e.g., financial) impact of a cyber incident
Extreme	Refers to a value taken from a loss distribution at the median value plus one standard deviation
Tail event	A value taken from a loss distribution at the 95th percentile
Entity	Refers to the organization that is under evaluation using the assessment methodology described herein
Data Disclosure	Refers to utilization of information technology to make sensitive information known to unauthorized recipients
Fraud	Refers to wrongful or criminal use of information technology intended to result in financial or personal gain
Business Interruption	Refers to cessation or degradation of an entity's operations based on cyber asset (e.g., information technology asset) failures or hacking

In some embodiments, the assessment methodology described herein can provide a comprehensive set of results that reflects the cumulative nature of an entity's security posture tempered by cyber events (e.g., attacks and incidents) that the entity has historically experienced and will likely experience in the future. Individual components of assessment methodology can be decoupled from the generated results and can provide decomposed insights relevant to specific consumers including, for example, Chief Information Security Officers (CISOs), Chief Risk Officers (CROs), Board Directors, internal audit, credit analysts, insurance underwriters, and others.

The methods and related systems disclosed herein provide for significant improvements in assessment and mitigation

In some embodiments, a combination of the indicators for governance and fortitude factors may represent a cyber security score for the entity, which may be independent of the entity's ability to withstand cyber events. A combination of the indicators for governance, fortitude, and risk factors may indicate the entity's ability to withstand such cyber events. Analysis used for the assessment methodology described herein may be decomposed into several scoring components that form a hierarchical model for evaluating cyber resilience and generating the cyber resilience rating for an entity. Exemplary levels, naming conventions, and examples for each level for the hierarchical model are described by Table 2.

TABLE 2

Hierarchical Model for Assessment Methodology

Level	Name	Examples
L0	Future Use	Proposed approaches described with respect to "Exemplary Scoring for a Cyber Resilience Rating"
L1	Factors	Threat, Fortitude, Risk, Governance
L2	Subfactors	Culture, Detection, Loss Exceedance Curves
L3	Capabilities	Behavior, Inventory, Boundary Defense
L4	Indicators	The vulnerability scans coverage of domain controllers is sufficient The authenticated vulnerability scans coverage of workstations is sufficient
L5	Signals	a ratio of an amount of an entity's domain controllers including vulnerabilities to a total number of the entity's domain controllers a ratio of an amount of an entity's workstations including vulnerabilities to a total number of an entity's workstations

The levels, naming conventions, and examples for each level for the hierarchical model shown in Table 2 are examples and may be supplemented, modified, and/or removed. The levels described with respect to Table 2 may be connected based on a number of relationships. Level L0 may include one or more ratings each corresponding to one or more factors. Level L1 may include the threat, fortitude, risk, and governance factors described herein, where each factor corresponds to one or more subfactors. Level L2 may include one or more subfactors each corresponding to one or more capabilities Level L3 may include one or more capabilities each corresponding to an indicator of the respective capabilities. Level L4 may include one or more indicators each corresponding to an obtained signal. Level L5 may include one or more obtained signals. FIGS. **1**A and **1**B depict exemplary diagrams **100***a* and **100***b*, respectively, of a hierarchical model for cyber resilience assessment, according to some embodiments. As shown in the diagrams **100***a* and **100***b*, the hierarchical model for the cyber resilience assessment methodology may include levels L0-L5, where level L0 is a top level of the hierarchy and level L5 is a bottom level of the hierarchy. Level L0 may correspond to one or more ratings **102**, including the cyber resilience rating and cyber security score described herein. Each of the ratings **102** may be based on the levels included under the level L0 corresponding to the ratings **102**. For example, the cyber resilience rating may be based on the governance, fortitude and risk factors, while the cyber security rating may be based on only the governance and fortitude factors. The cyber resilience rating and the cyber security score may not be based on the threat factor as described with respect to the diagram **100***b*.

As shown in FIGS. **1**A and **1**B, the level L1 may include one or more factors **104**, including threat, fortitude, risk, and governance factors described herein. Each factor **104** may be based on one or more subfactors **106** corresponding to the level L2. For example, the governance factor may be based on subfactors **106** for culture, strategy, resources, third-party affiliates, enterprise risk loss exposure management, and penetration testing and red team exercises relating to cyber security practices for an entity under evaluation via the assessment methodology described herein. The subfactors **106** described in the diagrams **100***a* and **100***b* may be exemplary and other subfactors **106** may correspond to each factor **104**. Each subfactor **106** may be based on one or more capabilities **108** corresponding to the level L3. For example, the culture subfactor may be based on capabilities **108** for behavior, communications, conformity, understanding, conduct, roles and responsibilities, and cyber security training awareness relating to cyber security practices for an entity under evaluation via the assessment methodology described herein. The capabilities **108** described in the diagrams **100***a* and **100***b* may be exemplary and other capabilities **108** may correspond to each subfactor **106**.

In some embodiments, each capability **108** may be derived from one or more indicators **110** corresponding to the level L4. The indicators **110** may provide information for each of the capabilities **108**. The indicators **110** may be derived from signals **112** corresponding to the level L5. Examples of signals **112** from which the indicators **110** may be derived include signal values, artifacts, and collection tools. Signals **112** may include cyber security information obtained for the entity under evaluation, including cyber security threat, event, and incident information and characteristics of the entity. Signals **112** may include and/or otherwise be derived from internally-observed and/or externally-observed cyber security threat, event, and/or incident information and characteristics of the entity. In some cases, signals **112** may include characteristics of entities that may be evaluated using a cyber resilience assessment tool as described herein, including information indicative of industries of each of the entities, geographical locations (e.g., geographical locations of headquarters) of each of the entities, and size. A size of an entity may be indicated by the entity's annual revenue, number of employees, and/or by another metric.

As used herein, an "affiliate" of a particular entity may be any individual, organization, corporation and/or other entity that interacts with, provides services to, and/or otherwise has a relationship to or with the particular entity.

As used herein, the "criticality" of an entity's relationship to an affiliate may be a measurement or characterization of the extent to which the entity's well-being (e.g., operational integrity, health, reputation, financial position, security state, etc.) is sensitive to (e.g., dependent on) the affiliate's well-being, the frequency of such interactions, the volume of data exchanged between the entity and any given affiliate, and/or the sensitivity of such data.

An entity may monitor the security status (e.g., security ratings, security events, etc.) of one or more of the entity's affiliates. The monitored affiliates may be referred to herein as the entity's "portfolio" of affiliates. An entity's portfolio may include any number of the entity's affiliates (e.g., one or more, dozens, hundreds, thousands, etc.).

"Characteristics" of an entity (e.g., an affiliate or other entity) may include, without limitation, size (e.g., the number of employees or other members of the entity, the entity's market capitalization or annual revenues, etc.); the business sector (e.g., industry, sub-industry, etc.) in which the entity operates (e.g., legal services, technology, finance, etc.); age; rate of growth; North American Industry Classification System (NAICS) code; Standard Industrial Classification (SIC) code; a number of services provided by the entity; a security rating (e.g., as provided by BitSight Technologies, Inc. of Boston, Massachusetts, USA); a geographical location of the entity; a location of the entity based on one or more IP addresses associated with the entity (e.g., "geo IP" footprint); a number of Internet Protocol (IP) addresses associated with the entity; the technology used by the entity (e.g., server software, user software, etc.); one or more security risk types of an entity; and/or known competitors or entities similar to the particular entity based on the web activity of the entity. Values for one or more of the above-listed entity characteristics may be provided by the entity itself, obtained from third party sources (e.g., a firmographics data source, data from BuiltWith® Pty Ltd), and/or collected or extracted from publicly available information. In some embodiments, the values for one or more entity characteristics can be stored in a database.

A "security profile" of an entity may reflect the past, present, and/or future security characteristics of an entity. In some embodiments, the security profile may reflect security risks to which the entity is exposed balanced by the countermeasures that the entity has taken or can take to mitigate the security risk. As referred to herein, a security profile of an entity can include a "security rating" (e.g., "security score") for the entity. A security rating may be quantitative or qualitative. For example, a quantitative security rating may be expressed as a number within a predetermined range (e.g., between 250 and 900, as provided by BitSight Technologies, Inc. of Boston, Massachusetts, USA). Some non-limiting examples of techniques for determining security ratings of entities are described in U.S. patent application Ser. Nos. 16/802,232, 13/240,572, 15/142,677, and 16/514,771.

As used herein, "monitoring" an affiliate may refer to determining (e.g., obtaining) a security rating of the affiliate from time to time, identifying one or more activities or events relevant to the affiliate's security profile, etc. Some non-limiting examples of techniques for determining security ratings of entities are described in U.S. patent application Ser. Nos. 16/802,232, 13/240,572, 15/142,677, and 16/514,771.

Some Embodiments of Cyber Resilience Assessment

To evaluate and assess an entity's cyber resilience based on the cyber resilience rating and factors (e.g., factors **102**) described herein, a cyber resilience assessment tool including assessment methodology of the hierarchical model described herein may be needed. Referring to FIG. **2**, an example of a cyber resilience assessment tool **200** is shown. In some embodiments, the cyber resilience assessment tool **200** may provide assessments of an entity's cyber resilience and cyber resilience of an entity's affiliates. Assessments of cyber resilience may include a cyber resilience rating and/or a cyber security score as described herein. Cyber resilience ratings and cyber security score may be derived from data obtained by a cybersecurity monitoring system. In some embodiments, the cyber resilience assessment tool **200** may be included with a cybersecurity monitoring system of a risk management service provider. Some non-limiting examples of cybersecurity monitoring systems are described in U.S. patent application Ser. Nos. 16/802,232, 13/240,572, 15/142,677, and 16/514,771. In some embodiments, the cyber resilience assessment tool **200** may be communicatively coupled to one or more third-party computing systems.

Some embodiments of a cyber resilience assessment tool **200** are described below. In some embodiments, the cyber resilience assessment tool **200** may include a data aggregation module **210**, a cyber resilience assessment module **220**, and a cyber resilience user interface **250**. The data aggregation module **210** may obtain signals (e.g., signals **112**) from one or more computing systems connected to the cyber resilience assessment tool **200**. The signals may include internally-observable and/or externally observable cyber security information corresponding to an entity under evaluation by the cyber resilience assessment tool **200**. Internally-observable cyber security information may be derived from an entity's computing systems, computing assets, and/or cyber protocols and practice. Externally-observable cyber security information may be derived from third-party entities that observe and monitor an entity's computing systems, computing assets, and/or cyber protocols and practice. Examples of signals obtained by the data aggregation module **210** can include:

- an amount of capital investment in the security of the entity;
- a measure of employee training in the security of the entity;
- a measure of organization of entity personnel dedicated to information security;
- an amount of the entity's budget dedicated to information security;
- a number and/or severity of botnet infection instances of a computer system associated with the entity;
- a number of spam propagation instances originating from a computer network associated with the entity;
- a number of malware servers associated with the entity;
- a number of potentially exploited devices associated with the entity;
- a number of hosts authorized to send emails on behalf of each domain associated with the entity;
- a determination of whether a DomainKeys Identified Mail (DKIM) record exists for each domain associated with the entity and/or a key length of a public key associated with a Domain Name System (DNS) record of each domain associated with the entity;
- an evaluation of a Secure Sockets Layer (SSL) certificate and/or a Transport Layer Security (TLS) certificate associated with a computer system of the entity;
- a number and/or type of service of open ports of a computer network associated with the entity;
- an evaluation of security-related fields of a header section of HTTP response messages of hosts associated with the entity;
- a rate at which vulnerabilities are patched in a computer network associated with the entity;
- an evaluation of file sharing traffic originating from a computer network associated with the entity; and/or
- a number of lost records and/or sensitivity of information in the lost records in a data breach of a computer system associated with the entity.

In some embodiments, signals may be provided to the cyber resilience assessment tool **200** via the cyber resilience user interface **250**. For example, information security administrators corresponding to an entity under evaluation may provide characteristics corresponding to the entity at the cyber resilience user interface **250**. The data aggregation module **210** may continuously and/or periodically obtain signal data based on an availability of the signal data from internal and/or external data sources.

In some embodiments, the cyber resilience assessment tool **200** may include a cyber resilience assessment module **220**. The cyber resilience assessment module **220** may receive data aggregated by the data aggregation module and may generate cyber resilience assessments for one or entities and/or affiliates of the entities. Cyber resilience assessments may include a cyber resilience rating and/or a cyber security score as described herein. The cyber resilience assessment module **220** may generate cyber resilience assessments including cyber resilience ratings based on the assessment methodology and methods described herein with respect to "Exemplary Scoring for a Cyber Resilience Rating". The cyber resilience assessment module **220** may utilize the scoring methodology for the governance, fortitude, and risk factors as described below.

In some embodiments, the cyber resilience assessment tool **200** may be implemented as software executed on one or more computer systems **400**. For example, the cyber resilience assessment tool **200** may be implemented as software executed on an entity's computer systems or a third party entity's computer systems, where the third party entity (e.g., risk management service provider) provides services to the entity. In some embodiments, the cyber resilience assessment tool **200** may provide a cyber resilience user interface **250**. The cyber resilience user interface **250** may present (e.g., display) generated cyber resilience assessments and may selection and analysis of individual components (e.g., factors **104**, subfactors **106**, capabilities **108**, indicators **110**, and/or signals **112**) of generated cyber resilience assessments for entities.

In some embodiments, the cyber resilience user interface **250** may provide interactive components whereby a user may interact with the data aggregation module **210** and/or the cyber resilience assessment module **220**. For example, by interacting with the cyber resilience user interface **250**, the user may modify data sources from which data is obtained by the data aggregation module **210** and may review and analyze generated cyber resilience assessments generated by the cyber resilience assessment module **220**.

Some embodiments of assessment methods and methodology for generating cyber resilience assessments are described in further detail below. In addition, some embodiments of a method **300** for providing a cyber resilience rating are described below.

Exemplary Scoring for a Governance Factor

In some embodiments, the cyber risk assessment module **220** may generate scoring for factors of a cyber resilience rating and/or a cyber security score. In some cases, the cyber risk assessment module **220** may generate a score for a governance factor. The governance factor may provide an indication of management of an entity's cyber security organization. Managing an entity's cyber security organization can require aligning the entity's cyber security culture, strategy, resources, third party affiliates, risk management, and penetration testing in furtherance of the business goals and objectives of entity. Such subfactors as described herein can be encapsulated in a generated governance score. In some embodiments, the governance factor may be scored on a 0-100 scale and is evaluated according to a rubric for the subfactors (e.g., subfactors **106**) of the governance factor as shown in Table 3. In some cases, the governance factor may be measured and weighted using various gradients and scales different from those described in Table 3.

TABLE 3

Governance Factor Scoring Methodology

Subfactor	Possible Points	Weight
Culture	0-100	(100/6)%
Strategy	0-100	(100/6)%
Resources	0-100	(100/6)%
Third Party Affiliates	0-100	(100/6)%
Enterprise Risk Loss Exposure Management	0-100	(100/6)%
Penetration Testing and Red Team Exercises	0-100	(100/6)%

As shown in Table 3, in this particular embodiment, each of the subfactors (e.g., subfactors **106**) may be scored on a scale of 0-100, multiplied by a respective weight, and summed to produce a score for the governance factor as described by Equation 1.

$$\text{Governance Factor Score} = \sum_{x=1}^{6} \text{Subfactor}_x * \text{Weight}_x \tag{1}$$

In this particular embodiment, each subfactor may be weighted evenly. In other embodiments, the weights may be altered to address entity-specific and/or industry-specific needs. The governance factor may be scored based on a weighted combination of the subfactors for culture, strategy, resources, third-party affiliates, enterprise risk loss exposure management, and penetration testing and red team exercises. Each individual subfactor may be scored independently as described below.

In some embodiments, a governance factor may include an entity's cyber security culture (referred to herein as "culture") as a subfactor. A score for an entity's culture subfactor may be based on one or more capabilities (e.g., capabilities **108**). Examples of capabilities indicative of the culture subfactor are described in Table 4.

TABLE 4

Culture Subfactor Scoring Methodology

Security Culture Capability	Points	Weight
Behavior	0-100	(100/7)%
Communications	0-100	(100/7)%
Conformity	0-100	(100/7)%
Understanding	0-100	(100/7)%
Conduct	0-100	(100/7)%
Roles and Responsibilities	0-100	(100/7)%
Security Awareness and Training	0-100	(100/7)%

The capabilities for the culture subfactor as shown in Table 4 can assess to what extent security expectations are present throughout an evaluated entity's organizational culture. The culture subfactor may be assessed by a number of indicators (e.g., indicators **110**) that quantify each of the capabilities described in Table 4. Indicators may be derived from signals (e.g., signals **112**) as described herein for the cyber resilience assessment tool **200**. In this particular embodiment, each of the capabilities may be scored on a scale of 0 to 100, multiplied by a respective weight, and then summed to produce a score for the culture subfactor as described by Equation 2.

$$\text{Culture Subfactor Score} = \sum_{x=1}^{7} Capability_x * Weight_x \tag{2}$$

In this particular embodiment, each capability may be weighted evenly. In other embodiments, the weights may be altered to address entity-specific and/or industry-specific needs.

In some embodiments, a governance factor may include an entity's cyber security strategy (referred to herein as "strategy") as a subfactor. The strategy subfactor can assess how well aligned the entity's cyber security organization is to the business served by the entity. A score for an entity's strategy subfactor may be based on one or more capabilities (e.g., capabilities **108**). Examples of capabilities indicative of the strategy subfactor and criteria for each capability are described in Table 5.

TABLE 5

Strategy Subfactor Scoring Methodology

Security Strategy Capability	Criteria	Points	Weight
Security Strategy Type	1. No security strategy 2. Documented security strategy 3. Documented multiyear security strategy	1. 0 2. 50 3. 100	20%
Security Strategy Drivers	1. Security primarily driven by firefighting needs 2. Security primarily driven by audit and compliance 3. Security primarily driven by alignment with corporate strategy, inclusive of all necessary obligations 4. Security primarily driven by a balance of corporate strategy in line with cyber risk appetite	1. 0 2. 25 3. 50 4. 100	20%
Regulatory Alignment	1. Regulatory requirements are not known or heeded 2. Entity develops ad-hoc regulatory requirements 3. Regulatory requirements are integrated into security policy and strategy	1. 0 2. 50 3. 100	20%
Policy and Standards	1. No security policy and standards 2. Published security policy and standards 3. Security policy and standards are published and approved by business leaders	1. 0 2. 50 3. 100	20%
Issues/ Findings Prioritiza-tion	1. No issue/findings prioritization 2. Issues/findings prioritized by non-business stakeholders 3. Issues/findings prioritized to meet business and regulatory requirements	1. 0 2. 50 3. 100	20%

The strategy subfactor may be based on one or more capabilities and corresponding criteria as shown in Table 5. The highest level of performance for each capability may be the assigned score for the respective criteria corresponding to the entity for the respective capabilities, such that assigned scores are not cumulative for each categorical assessment of the criteria. The strategy subfactor may be assessed by a number of indicators (e.g., indicators **110**) that map to one of the criteria for each of the capabilities described in Table 5. Indicators may be derived from signals (e.g., signals **112**) as described herein for the cyber resilience assessment tool **200**. In this particular embodiment, each of the capabilities may be scored on a scale of 0 to 100 based on the corresponding criteria of the entity corresponding to the respective capabilities, multiplied by a respective weight, and then summed to produce a score for the strategy subfactor as described by Equation 3.

$$\text{Strategy Subfactor Score} = \sum_{x=1}^{5} Capability_x * Weight_x \tag{3}$$

In this particular embodiment, each capability may be weighted evenly. In other embodiments, the weights may be altered to address entity-specific and/or industry-specific needs.

In some embodiments, a governance factor may include an entity's funding and/or available resources for cyber security (referred to herein as "resources") as a subfactor. A score for an entity's resources subfactor may be based on one or more capabilities (e.g., capabilities **108**). A resources subfactor indicative of a well-funded security organization may be a prerequisite for adequate cyber security execution and subsequent risk management. A resources subfactor may indicate an entity's allocation of resources (e.g., funding) for cyber security functions. A resources subfactor may indicate which of the following groups of an entity receive resources for cyber security, including (but not limited to): Asset Management; Penetration Testing and Red Teaming; Identify and Access Management; IT/Cyber Risk Management; Networking and Telecommunications; Security/Business liaisons (BISOs); Security Operations; Security Technology and Architecture; Cloud Security; and Threat Intelligence. Examples of capabilities indicative of the resource subfactor and criteria for each capability are described in Table 6.

TABLE 6

Resource Subfactor Scoring Methodology

Resource Capability	Criteria	Points	Weight
Budgeting Process	1. Ad-hoc funding for security 2. Annual Security Budget 3. Multi-year Security budget	1. 0 2. 50 3. 100	50%
Budget Priorities	Ten points for each area that is funded 1. Asset Management 2. Penetration Testing and Red Teaming 3. Identify and Access Management 4. IT/Cyber Risk Management 5. Networking and Telecommunications 6. Security/Business liaisons (BISOs) 7. Security Operations 8. Security Technology and Architecture 9. Cloud Security 10. Threat Intelligence	0-100	50%

The resources subfactor may be based on one or more capabilities and corresponding criteria as shown in Table 6. The resource subfactor may be assessed by a number of indicators (e.g., indicators **110**) that map to one of the criteria for each of the capabilities described in Table 6. Indicators may be derived from signals (e.g., signals **112**) as described herein for the cyber resilience assessment tool **200**. In this particular embodiment, each of the capabilities may be scored on a scale of 0 to 100 based on the corresponding criteria of the entity, multiplied by a respective weight, and then summed to produce a score for the resources subfactor as described by Equation 4.

$$\text{Resources Subfactor Score} = \sum_{x=1}^{2} Capability_x * Weight_x \tag{4}$$

In this particular embodiment, each capability may be weighted evenly. In other embodiments, the weights may be altered to address entity-specific and/or industry-specific needs.

In some embodiments, a governance factor may include an entity's visibility and management of affiliates (e.g., supply chain providers, vendors, and/or third parties having relationships with the entity) of the entity (referred to herein as "third-party affiliates") as a subfactor. A score for an entity's third-party affiliates subfactor may be based on one or more capabilities (e.g., capabilities **108**). Examples of capabilities indicative of the third-party affiliates subfactor and criteria for each capability are described in Table 7.

TABLE 7

Third-Party Affiliates Subfactor Scoring Methodology

Third-Party Affiliates Capability	Points	Weight
Inventory	0-100	12.5%
Onboarding	0-100	12.5%
Risk-Based Approach	0-100	12.5%
Due Diligence	0-100	12.5%
Continuous Monitoring	0-100	12.5%
Oversight	0-100	12.5%
Incident Response and Recovery	0-100	12.5%
Roles and Responsibilities	0-100	12.5%

The third-party affiliates subfactor may be assessed by a number of indicators (e.g., indicators **110**) that quantify each of the capabilities described in Table 7. Indicators may be derived from signals (e.g., signals **112**) as described herein for the cyber resilience assessment tool **200**. The indicators may indicate the entity's performance for each capability and the capabilities may be cross-referenced to popular security and control frameworks. In this particular embodiment, each of the capabilities may be scored on a scale of 0 to 100, multiplied by a respective weight, and then summed to produce a score for the third-party affiliates subfactor as described by Equation 5.

$$\text{Third Party Affiliates Subfactor Score} = \sum_{x=1}^{8} Capability_x * Weight_x \tag{5}$$

In this particular embodiment, each capability may be weighted evenly. In other embodiments, the weights may be altered to address entity-specific and/or industry-specific needs.

In some embodiments, a governance factor may include an assessment of whether and/or to what extent an entity is capable of withstanding extreme and tail cyber loss events strategy (referred to herein as "enterprise risk loss exposure management" or "risk management") as a subfactor. For example, the enterprise risk loss exposure management subfactor may measure whether an entity has appropriate insurance coverage and/or if the entity conducts capital allocation or self-insurance exercises with specific cyber loss scenarios. A score for an entity's enterprise risk loss exposure management subfactor may be based on one or more criteria. Examples of criteria indicative of the enterprise risk loss exposure management subfactor are described in Table 8.

TABLE 8

Enterprise Risk Loss Exposure Management Subfactor Scoring Methodology

Criteria	Score
No insurance or reserves	0
Reserves or insurance	50
Reserves and Insurance	100

The enterprise risk loss exposure management subfactor may be assessed by a number of indicators (e.g., indicators **110**) that indicate the criteria described in Table 8. Indicators may be derived from signals (e.g., signals **112**) as described herein for the cyber resilience assessment tool **200**. Based on the criteria shown in Table 8, a score may be produced for the enterprise risk loss exposure management subfactor as described by Equation 6.

$$\text{Risk Management Subfactor Score} = \text{Criteria Score} \tag{6}$$

In some embodiments, a governance factor may include an assessment of a degree to which an entity is engaged in mature penetration testing and red teaming activities to test their control environment and identify deficiencies (referred to herein as "penetration testing and red team exercises") as a subfactor. A score for an entity's penetration testing and red team exercises subfactor may be based on one or more capabilities (e.g., capabilities **108**). Examples of capabilities indicative of the penetration testing and red team exercises subfactor and criteria for each capability are described in Table 9.

TABLE 9

Penetration Testing And Red Team Exercises Subfactor Scoring Methodology

Capability	Criteria	Score	Weight
Type	1. Entity does not perform a vulnerability or penetration test 2. Entity performs a basic vulnerability or penetration test 3. Entity performs a multi-layered attack simulation utilizing both social and technology attacks	1. 0 2. 50 3. 100	25%
Scope	1. Entity does not perform a vulnerability or penetration test 2. Limited scope/specific targets are designated out of scope (affecting mission/business objectives) 3. Broad scope (virtually nothing is off limits)	1. 0 2. 50 3. 100	25%
Frequency	1. Entity does not perform a vulnerability or penetration test 2. Conducted at least every other year 3. Conducted at least annually	1. 0 2. 50 3. 100	25%
Operator	1. Entity does not perform a vulnerability or penetration test 2. Conducted by internal staff only 3. Conducted by external staff 4. Conducted by a different external providers each time	1. 0 2. 33 3. 66 4. 100	25%

The penetration testing and red team exercises subfactor may be based on one or more capabilities and corresponding criteria as shown in Table 9. The penetration testing and red team exercises subfactor may be assessed by a number of indicators (e.g., indicators **110**) that map to one of the criteria for each of the capabilities described in Table 9. Indicators may be derived from signals (e.g., signals **112**) as described herein for the cyber resilience assessment tool **200**. In this particular embodiment, each of the capabilities may be scored on a scale of 0 to 100 based on the corresponding criteria of the entity, multiplied by a respective weight, and then summed to produce a score for the penetration testing and red team exercises subfactor as described by Equation 7.

$$\text{Penetration Testing \& Red Teaming Subfactor Score} = \sum_{x=1}^{4} Capability_x * Weight_x \tag{7}$$

In this particular embodiment, each capability may be weighted evenly. In other embodiments, the weights may be altered to address entity-specific and/or industry-specific needs.

As described herein, the cyber resilience assessment tool **200** may determine the governance factor score based on a weighted sum of the individual scores for one or more subfactors, including culture, strategy, resources, third-party affiliates, enterprise risk loss exposure management, and penetration testing and red team exercises. In some embodiments, alternate scoring combinations to determine the score for the governance factor of the cyber resilience rating and the cyber security score may be used by the cyber resilience assessment tool **200**.

Exemplary Scoring for a Fortitude Factor

In some cases, the cyber risk assessment module **220** may generate a score for a fortitude factor. The fortitude factor may provide an indication of an entity's security posture, including the entity's ability to prevent and withstand the impact of cyber events (e.g., incidents). An entity's security posture and assessed score for a fortitude factor may be based on subfactors including a protection, detection, and response subfactor. Such subfactors as described herein can be encapsulated in a generated fortitude score. In some embodiments, the fortitude factor may be scored on a 0-100 scale and is evaluated according to a rubric for the subfactors (e.g., subfactors **106**) of the fortitude factor as shown in Table 10. The score for the fortitude factor may be weighted evenly between controls that affect loss events from occurring (e.g., as indicated by the protection factor) and controls that affect the amount of losses an entity might incur (e.g., as indicated by the detection and response factors). In some cases, the fortitude factor may be measured and weighted using various gradients and scales different from those described in Table 10.

TABLE 10

Fortitude Factor Scoring Methodology

Subfactor	Possible Points	Weight
Protection	0-100	50%
Detection/Response	0-100	50%

As shown in Table 10, in this particular embodiment, each of the subfactors (e.g., subfactors **106**) may be scored on a scale of 0-100, multiplied by a respective weight, and summed to produce a score for the fortitude factor as described by Equation 8.

$$\text{Fortitude Factor Score} = (\text{Protection}_{Score} * \text{Protection}_{Weight}) + (\text{Detection Response}_{Score} * \text{Detection Response}_{Weight}) \quad (8)$$

In this particular embodiment, each subfactor may be weighted evenly. In other embodiments, the weights may be altered to address entity-specific and/or industry-specific needs. Each individual subfactor may be scored independently as described below.

In some embodiments, a fortitude factor may include an entity's protection controls (referred to herein as "protection") as a subfactor. An entity's protection controls may be represented by a number of control evaluations focused on technologies and practices that prevent an attacker or insider from initiating a data disclosure, fraud, and/or business interruption event. A score for an entity's protection subfactor may be based on one or more capabilities (e.g., capabilities **108**). Examples of capabilities indicative of the protection subfactor are described in Table 11.

TABLE 11

Protection Subfactor Scoring Methodology

Protection Capability	Points	Weight
Application Software Security	1-100	(100/12)%
Asset Inventory	1-100	(100/12)%
Boundary Defense	1-100	(100/12)%
Browser Security	1-100	(100/12)%
Data Protection	1-100	(100/12)%
Email Security	1-100	(100/12)%
Identity and Access Management	1-100	(100/12)%
Network Protection	1-100	(100/12)%
Secure Network Device Configuration	1-100	(100/12)%
Secure Server Configuration	1-100	(100/12)%
Secure Workstation Configuration	1-100	(100/12)%
Vulnerability Management	1-100	(100/12)%

The protection subfactor may be based on one or more capabilities as shown in Table 11. The protection subfactor may be assessed by a number of indicators (e.g., indicators **110**) that quantify each of the capabilities described in Table 11. Indicators may be derived from signals (e.g., signals **112**) as described herein for the cyber resilience assessment tool **200**. Each of the capabilities shown in Table 11 and the indicators mapped to the respective capabilities may be cross-referenced to popular security and control frameworks and practices. Each capability may have a series of control test indicators used to determine how well the entity is performing in the respective capability. In this particular embodiment, each of the capabilities may be scored on a scale of 0 to 100, multiplied by a respective weight, and then summed to produce a score for the protection subfactor as described by Equation 9.

$$\text{Protection Subfactor Score} = \sum_{x=1}^{12} Capability_x * Weight_x \quad (9)$$

In this particular embodiment, each capability may be weighted evenly. In other embodiments, the weights may be altered to address entity-specific and/or industry-specific needs. Some or all of the indicators that are scored for each capability in Table 11 may be distributed via a Z-Score function and indexed to peer benchmarks, to allocate the point spread across the number of indicators being assessed.

In some embodiments, a fortitude factor may include an entity's detection controls and response controls (referred to herein as "detection and response") as a subfactor. An entity's detection controls may be represented by a number of control evaluations focused on technologies and practices that allow an entity to detect the actions of an individual (e.g., attacker or insider) as the individual perpetrates a data disclosure, fraud, and/or business interruption event. An entity's response controls may be represented by a number of control evaluations focused on technologies and practices that allow an entity to respond to the actions of an individual (e.g., attacker or insider) as the individual perpetrates a data disclosure, fraud, and/or business interruption event. A score for an entity's detection and response subfactor may be based on one or more capabilities (e.g., capabilities **108**). Examples of capabilities indicative of the detection and response subfactor are described in Table 12.

TABLE 12

Detection and Response Subfactor Scoring Methodology

Detection/Response Capability	Points	Weight
Logging	0-100	25%
Monitoring and Alerting	0-100	25%
Business Continuity Planning (BCP) and Data Recovery	0-100	25%
Incident Response and Management	0-100	25%

The detection and response subfactor may be based on one or more capabilities as shown in Table 12. The detection and response subfactor may be assessed by a number of indicators (e.g., indicators **110**) that quantify each of the capabilities described in Table 12. Indicators may be derived from signals (e.g., signals **112**) as described herein for the cyber resilience assessment tool **200**. Each of the capabilities shown in Table 12 and the indicators mapped to the respective capabilities may be cross-referenced to popular security and control frameworks and practices. Each capability may have a series of control test indicators used to determine how well the entity is performing in the respective capability. In this particular embodiment, each of the capabilities may be scored on a scale of 0 to 100, multiplied by a respective weight, and then summed to produce a score for the protection subfactor as described by Equation 10.

$$\text{Detection \& Response Subfactor Score} = \sum_{x=1}^{4} Capability_x * Weight_x \tag{10}$$

In this particular embodiment, each capability may be weighted evenly. In other embodiments, the weights may be altered to address entity-specific and/or industry-specific needs. Some or all of the indicators that are scored for each capability in Table 12 may be distributed via a Z-Score function and indexed to peer benchmarks, to allocate the point spread across the number of indicators being assessed. In some cases, the detection and response subfactor score may be assessed by outside-in and/or inside-out assessments for an entity.

As described herein, the cyber resilience assessment tool **200** may determine the fortitude factor score based on a weighted sum of the individual scores for one or more subfactors, including protection and detection and response. In some embodiments, alternate scoring combinations to determine the score for the fortitude factor of the cyber resilience rating and the cyber security score may be used by the cyber resilience assessment tool **200**.

Exemplary Scoring for a Risk Factor and Peer Group Analysis

In some cases, the cyber risk assessment module **220** may generate a score for a risk factor. The risk factor may provide an indication of an entity's quantified cyber risk using cyber risk quantification (CRQ) methods (e.g., methods as articulated in the Open FAIR standards). A score for the risk factor may be assessed based producing an exceedance probability (EP) curve and related cyber loss simulation data that represents the entity's loss potential (e.g., economic and/or financial loss potential) and related probability of such loss potential. Each EP curve may include a continuous or discrete graph of loss values (also referred to as "loss amounts") plotted against respective probabilities that the entity's losses for a period of time (e.g., 1 year, 5 years, 10 years, etc.) exceed the loss values. Each EP curve may be generated based on estimated loss values corresponding to simulations of cyber loss events performed using Monte Carlo analysis. Executed simulations of cyber loss events and corresponding loss values for an entity based on Monte Carlo analysis may be referred to herein as "cyber loss simulation data". In some cases, the EP curve may also be referred to as a Loss Exceedance Curve (LEC). In some embodiments, the risk factor may be scored on a 0-10 scale and an intersection of the entity's materiality may be plotted on the probability axis of the EP curve and the entity's resultant EP value may be evaluated according to one of the rubrics (Option 1 or Option 2) as shown in Table 13. The EP value may be determined based on a probability corresponding to an entity's materiality value, where the materiality value may be equivalent to an entity's materiality threshold (e.g., as described with respect to Table 20) multiplied by the entity's gross revenue (e.g., annual gross revenue).

TABLE 13

Risk Factor Scoring Methodology

EP Value	Score
Option 1	
>=0%-< 11%	10
>=11%-< 21%	9
>=21%-< 31%	8
>=31%-< 41%	7
>=41%-< 51%	6
>=51%-< 61%	5
>=61%-< 71%	4
>=71%-< 81%	3
>=81%-< 91%	2
>=91%	1
Option 2	
>=0% to <=1%	10
>1% to <=6%	9
>6% to <=15%	8
>15% to <=25	7
>25% to <=35%	6
>35% to <=45%	5
>45% to <=55%	4
>55% to <=65%	3
>65% to <=75%	2
>75%	1

The risk factor may quantitatively assess an entity's financial loss exposure based on data sets comprised of entity cohorts (also referred to as "peer entities") that have experienced similar events to the entity under evaluation. Selection of peer entities for an entity under evaluation may be executed as described below.

To generate the EP curve for an entity and to assess a score for the risk factor, the cyber resilience assessment module **220** may perform peer group analysis to identify peer entities and events for an entity. Peer group analysis may be conducted on entities for the purpose of selecting a sampling of (i) entities that are peers of an entity; and (ii) events experienced by those entities that are suitable for comparison. Peer group analysis for an entity may include multiple phases, including phase one (referred to as "peer entity analysis") and phase two (referred to as "event selection"), where performance of phase one may be a prerequisite to performing phase two. Phase one filtering may not have a minimum number of entities. A sufficient selection of records in phase two may be 10 records. Alternative numbers of records for phase **2** may be used. In phases one and two and for all levels of analysis, a timeline for comparison between entities may be events that have occurred in the past 10 years. In some cases, alternative time periods for event comparison may be used, such as 1, 2, 4, 8, or 16 years. Peer group analysis may group an entity with peer entities based on one or more groupings of analysis as described in Table 14, including global, sector, region, cluster, and cohort groupings. Additional groups may be used as described in Table 14.

TABLE 14

Groupings for Peer Selection Analysis for an Entity

	Grouping	Industry	Geography	Size
1	Global	All industry codes	All Geographies	All Sizes
2	Sector	2-digit North American Industry Classification System (NAICS) code	All Geographies	All Sizes
3	Region	2-digit NAICS code	Same Geographical Region (NA, SA, CALA, EMEA, APAC)	All Sizes
4	Cluster	4-digit NAICS code	Same Country	All Sizes
5	Cohort	4-digit NAICS code	Same Country	Same Operating Revenue Bin
6	Reserved for Future Use	6-digit NAICS code	Same Country	Same Operating Revenue Bin
7	Reserved for Future Use	6-digit NAICS code	More granular country region	Same Operating Revenue Bin

As described in Table 14, an entity may be grouped with peer entities in global, sector, region, cluster, and cohort groupings (e.g., in order of least granular to most granular groupings). To compare the industries, regions, and sizes of entities, the data aggregation module **210** may receive and/or otherwise obtain entity indicator data for each entity evaluated by the cyber resilience assessment tool **200**. Entity indicator data may include a number of entity indicators (e.g., such as tuples) that are indicative of characteristics of each entity evaluated by the cyber resilience assessment tool **200**. Each indicator may include one or more indicators for each of an entity's industry (e.g., indicated by NAICS codes or any other suitable industry identifier), geographic region (e.g., such as continent, country, state/province, city, and/or any other geographic indicator), and size (e.g., indicated by revenue, number of employees, etc.). Peer entities within each grouping for an entity may have an industry, region, and size (e.g., revenue) as described by Table 14 with respect to the entity. For example, peer entities of the entity in the global grouping may be entities of all industry codes, all geographies and all sizes, while peer entities of the entity in the cohort grouping may be entities having the same 4-digit NAICS code as the entity, located in the same country as the entity, and having the same bin (e.g., categorical assessment) of operating revenue as the entity. While an industry of an entity may be indicated with respect to NAICS codes (e.g., 2, 4, or 6-digit NAICS codes), any suitable identifier for an entity's industry may be used for peer group analysis as described herein.

As a part of phase one of peer group analysis for an entity, the cyber resilience assessment module **220** may perform global peer analysis. For global peer analysis, no filters may be applied the potential peer entities available for comparison, thereby establishing a baseline group of entities (also referred to as a "peer entity group") from which to compare any single entity. All entities may be able to be compared at the global peer analysis level.

Based on performing global peer analysis, the cyber resilience assessment module **220** may perform sector peer analysis, which may filter the group of peer entities determined in the global peer analysis based on the industry corresponding to the entity under evaluation. To filter the group of peer entities, the cyber resilience assessment module **220** may remove entities from the peer entity group that have an industry code (e.g., two-digit NAICS code) different from the respective code of the entity under evaluation, such that the only entities that have the same code as the entity remain in the group of peer entities. Sector peer analysis may select all entities within the same industry as the entity under evaluation for inclusion in the group of peer entities. Examples of industry codes used to perform sector peer analysis are described in Table 15.

TABLE 15

Industry Codes for Sector Peer Analysis

Code	Industry Title
11	Agriculture, Forestry, Fishing and Hunting
21	Mining
22	Utilities
23	Construction
31-33	Manufacturing
42	Wholesale Trade
44-45	Retail Trade
48-49	Transportation and Warehousing
51	Information
52	Finance and Insurance
53	Real Estate Rental and Leasing
54	Professional, Scientific, and Technical Services
55	Management of Companies and Enterprises
56	Administrative and Support and Waste Management and Remediation Services
61	Educational Services
62	Health Care and Social Assistance
71	Arts, Entertainment, and Recreation
72	Accommodation and Food Services
81	Other Services (except Public Administration)
92	Public Administration

Based on performing sector peer analysis, the cyber resilience assessment module **220** may perform region peer analysis, which may filter the group of peer entities determined in the sector peer analysis based on the geographical region corresponding to the entity under evaluation. To filter the group of peer entities, the cyber resilience assessment module **220** may remove entities from the peer entity group that correspond to a different geographical region from the respective geographical region of the entity under evaluation, such that the only entities that have the same geographical region as the entity remain in the group of peer entities. Region peer analysis may select all entities within the same geographic region as the entity under evaluation for inclusion in the group of peer entities. In some cases, an entity referred to as corresponding to a geographic region may be geographically located in the geographic region or headquartered in the geographic region. Examples of geographic regions used to perform region peer analysis are described in Table 16.

TABLE 16

Regions for Region Peer Analysis

Code	Region
NA	North America
SA	South America
CALA	Central and Latin America
EMEA	Europe, Middle East, and Africa
APAC	Asia Pacific

Based on performing region peer analysis, the cyber resilience assessment module **220** may perform cluster peer analysis, which may filter the group of peer entities determined in the region peer analysis based on an industry code (e.g., 4-digit NAICS code) and the country corresponding to the entity under evaluation. To filter the group of peer entities, the cyber resilience assessment module **220** may remove entities from the peer entity group that correspond to a different country from the respective country of the entity under evaluation, such that the only entities that have the same country as the entity remain in the group of peer entities. To filter the group of peer entities, the cyber resilience assessment module **220** may remove entities from the peer entity group that correspond to a different industry from the respective industry of the entity under evaluation, such that the only entities that have the same 4-digit NAICs code as the entity remain in the group of peer entities. Cluster peer analysis may select all entities within the same country and with the same 4-digit NAICS code as the entity under evaluation for inclusion in the group of peer entities. In some cases, an entity referred to as corresponding to a country may be geographically located in the country or headquartered in the country. Examples of industry codes used to perform cluster peer analysis are described in Table 17.

TABLE 17

Industry Codes for Cluster Peer Analysis

Code	Title
5211	Monetary Authorities-Central Bank
5221	Depository Credit Intermediation
5222	Non-depository Credit Intermediation
5223	Activities Related to Credit Intermediation
5231	Securities and Commodity Contracts Intermediation and Brokerage
5232	Securities and Commodity Exchanges
5241	Insurance Carriers
5251	Insurance and Employee Benefit Funds

Based on performing cluster peer analysis, the cyber resilience assessment module **220** may perform cohort peer analysis, which may filter the group of peer entities determined in the cluster peer analysis based on a respective revenue bin corresponding to the revenue (e.g., annual revenue) of the entity under evaluation. Cohort peer analysis may be the most granular of the groupings produced by the peer analysis as described herein. To filter the group of peer entities, the cyber resilience assessment module **220** may obtain a revenue for the entity under evaluation and may determine a revenue bin mapped to the entity's revenue. Based on the mapping, the cyber resilience assessment module **220** remove entities from the peer entity group that correspond to a different revenue bin (e.g., size as described in Table 18) from the respective revenue bin of the entity under evaluation, such that the only entities that have the same revenue bin as the entity remain in the group of peer entities. Cohort peer analysis may select all entities within the same revenue bin as the entity under evaluation for inclusion in the group of peer entities. Examples of revenue bins used to perform cohort peer analysis are described in Table 18. The revenue bins used for cohort peer analysis may deviate from the revenue bins described in Table 18 by using different minimum and/or maximum revenue thresholds for each bins and/or including a different number of bins.

TABLE 18

Revenue Bins for Cohort Peer Analysis

Size	Min	Max
Very Large	>$130M USD	n/a
Large	>$13M USD	<$130M USD
Medium	>$1.3M USD	<$13M USD
Small	>$0 USD	<$1.3M USD

While peer analysis for certain groupings is described herein as being based on other levels of peer analysis, the cyber resilience assessment module **220** may directly perform peer analysis for any of the groupings (e.g., global, sector, region, cluster, and cohort) described herein based on the criteria described in Table 14 without performing peer analysis for any other grouping as a prerequisite. Based on the peer analysis as described herein, peer entity groups may be generated for an entity under evaluation at any and/or all of the global, sector, region, cluster, and cohort groupings.

Based on performing phase one of peer group analysis to determine peer entity group(s) for the entity, as a part of phase two of peer group analysis, the cyber resilience assessment module **220** may perform record selection (e.g., for a minimum selection of 10 records) for one or more loss event types. Examples of loss event types for record selection are described in Table 19. Table 19 further describes an exemplary set of fields that may be used to determine which loss event records correspond to (e.g., are mapped to) a particular loss event type.

TABLE 19

Loss Event Types for Record Selection

Loss Event Type Classification	Record Categories
Data disclosure (DD)	Data-Malicious Breach Data-Physically Lost or Stolen Data-Unintentional Disclosure
Business Interruption (BI)	Cyber Extortion Network/Website Disruption
Fraud (FR)	Identity-Fraudulent Use/Account Access Phishing, Spoofing, Social Engineering Skimming, Physical Tampering
Privacy (PR)	Privacy-Unauthorized Contact or Disclosure
Reserved for Future Use	Privacy-Unauthorized Data Collection

The cyber resilience assessment module **220** may select event records for each of the loss event types described in Table 19. The event records may correspond to events experienced by entities in a peer entity group of the entity under evaluation and may be randomly sampled from available event records obtained for the peer entity group. As an example, event records may be derived from and/or included in signals (e.g., signals **112**) obtained by the cyber resilience assessment tool **200**. Each event record may include an indication of a loss event type and a loss value (e.g., financial and/or economic loss value) experienced by the peer entity to which the event record corresponds. A minimum number (e.g., 10) of event records may be selected for each loss event type. For each loss event type, event records may be initially selected from event records corresponding to peer entities of a peer entity group at a cohort filtering level. If a number of records available for the peer entity group at the cohort filtering level is less than the minimum number (e.g., 10) of selected event records, the peer entity group may change by a single level (e.g., cohort to cluster, cluster to region, region to sector, etc.) of granularity until the minimum number of event records is available for selection for each loss event type. For example, based on determining less than a minimum number of event records are available for the Fraud loss event type for the peer entity group at the cohort filtering level, the cyber resilience assessment module **220** may determine a number of records available for the Fraud loss event type for the peer entity group at the cluster filtering level, which may have more than the minimum number of event records available. Based on the selected loss event records for each loss event type, the cyber resilience assessment module **220** may determine an EP curve for each loss event type as described herein.

In some embodiments, the available loss event records for a peer entity group of an entity under evaluation can be further filtered based on the primary and secondary controls that have contributed to a loss event. Based on such filtering, the loss event records may be more specific and/or otherwise applicable to an evaluated entity's control posture. This filter may use an indication (e.g., list) of control tests being performed against an evaluated entity and an indication (e.g., list) of event records selected using the peer group analysis methodology described herein. Based on such filtering, the event records selected for peer comparison may reflect the corresponding failed, missing, and/or compromised controls as the controls corresponding to the entity.

In some embodiments, to determine a score for the risk factor as described herein, the cyber resilience assessment module **220** may generate cyber loss simulation data and one or more related EP curves. Cyber loss simulation data and each EP curve may be generated based on the selection of loss event records and included loss values obtained from peer entity group(s). The EP curve may represent the potential loss values for the entity and corresponding probabilities segmented into three high-level scenarios that each correspond to one of the loss event types described herein, including DD, BI, and FR loss event types. The EP curve may provide a probabilistic view of the loss potentials of the entity under evaluation, such that the EP curve provides a graphical representation of the probability that a certain level of loss will be exceeded. This EP curve can be generated (e.g., computed) using one or more (e.g., four) methods based on an availability of data as indicated below, where each method may generate an EP curve indicating a unique views of an entity's loss potential. In some cases, three EP curves may be generated for an evaluated entity to represent the possible loss values and corresponding probabilities for each of loss event types described herein (e.g., DD, BI, and FR loss event types). Based on data availability (e.g., availability of event records for each loss event type), three EP curves may be generated for each entity to illustrate the confidence level of cyber loss exposure for which an entity is susceptible.

In some embodiments, the cyber resilience assessment module **220** may generate an uncalibrated EP curve (also referred to as a "level one EP curve" or "L1 EP curve"). The uncalibrated EP curve may be a default curve generated by the cyber resilience assessment module **220** for evaluation of an entity. The uncalibrated EP curve may be generated based only on a loss potential of the peer entity group of an entity. For generation of an uncalibrated EP curve, the minimum, maximum, mode, and/or lambda values for the range of loss values from the selected loss event records may be computed and provided as an input for a number of Monte Carlo simulations. The minimum, maximum, and mode values for the range of loss values from the selected loss event records may be used to generate a beta PERT distribution, where the generated beta PERT distribution may be used as an input distribution from which to execute a number of Monte Carlo simulations (also referred to as "iterations"). The lambda value for the range of loss values from the selected loss event records may be a kurtosis value computed from the generated beta PERT distribution. Output cyber loss simulation data of the number of executed Monte Carlo simulations may be used to generate the uncalibrated EP curve.

In some embodiments, the cyber resilience assessment module **220** may generate an outside-in calibrated EP curve (also referred to as a "level two EP curve" or "L2 EP curve"). The outside-in calibrated EP curve may be generated when outside-in assessment results are available and/or otherwise included in the signals **112**. For generation of the outside-in calibrated EP curve, a 1 to 100 outside-in score may be used to select a loss value from the 25^{th} to the 75^{th} percentile of the range of loss values from the selected loss event records. The minimum and maximum values for the range of loss values from the selected loss event records and the loss value at the loss percentile that corresponds to the outside-in score may be computed and provided as an input for a number of Monte Carlo simulations. The minimum and maximum values for the range of loss values from the selected loss event records and the selected loss value (e.g., functioning as the mode value of the loss values) may be used to generate a beta PERT distribution, where the generated beta PERT distribution may be used as an input distribution from which to execute a number of Monte Carlo simulations. Output cyber loss simulation data of the number of executed Monte Carlo simulations may be used to generate the outside-in calibrated EP curve.

In some embodiments, the cyber resilience assessment module **220** may generate an survey-input/self-attestation calibrated EP curve (also referred to as a "level three EP curve" or "L3 EP curve"). The survey-input/self-attestation calibrated EP curve may be generated when a customer has provided answers to survey questions (e.g., obtained by the data aggregation module **210**). The survey-input/self-attestation calibrated EP curve may an internal representative view of an entity's control posture.

In some embodiments, the cyber resilience assessment module **220** may generate an inside-out calibrated EP curve (also referred to as a "level four EP curve" or "L4 EP curve"). The inside-out calibrated EP curve may be generated when there are inside-out assessment results available. For generation of the inside-out calibrated EP curve, a 1 to 100 inside-out score may be used to select a loss value from the 25^{th} to the 75^{th} percentile of the range of loss values from the selected loss event records. The minimum and maximum values for the range of loss values from the selected loss event records and the loss value at the loss percentile that corresponds to the inside-out score may be computed and provided as an input for a number of Monte Carlo simulations. The minimum and maximum values for the range of loss values from the selected loss event records and the selected loss value (e.g., functioning as the mode value of the loss values) may be used to generate a beta PERT distribution, where the generated beta PERT distribution may be used as an input distribution from which to execute a number of Monte Carlo simulations. Output expected loss results of the number of Monte Carlo simulations are used to generate the inside-out calibrated EP curve.

In some embodiments, one or more of the EP curves described herein may be combined to generate a combination EP curve derived from number of validated sources. For example, an entity's outside-in calibrated EP curve results can be combined with a survey-input/self-attestation calibrated EP curve to produce a combination EP curve. In some cases, an entity (via the cyber resilience assessment tool **200**) can entirely skip the assessments for generating a survey-input/self-attestation calibrated EP curve and may directly cause generation of an inside-out calibrated EP curve. The cyber resilience assessment tool **200** may generate an inside-out calibrated EP curve by mapping the indicators of each assessment to each other and choosing the values with the most validity to produce an aggregate curve. The validity of each of the EP curves may increase as the level of each EP curve increases from level one to level four. In some cases, the L2 and L3 EP curves may have similar levels of validity.

In some embodiments, an intersection of a materiality threshold relative to a probability of an EP curve may be selected for scoring of the risk factor. The methods and procedures for determining an entity's materiality threshold are described below.

To enhance assessment and scoring of the risk factor, the cyber resilience assessment module **220** may determine a financial materiality threshold for an entity under evaluation. In one example, a financial materiality can be assessed based on 2%-10% of an entity's gross revenue (e.g., as reported by the Bureau van Dijk Orbis firmographic database). Table 20 describes an exemplary set of materiality thresholds (MTs) that may be used to determine the probability for scoring the risk factor when plotted on an EP curve.

TABLE 20

Materiality Threshold and Criteria

Industry	NAICS Codes	Materiality Threshold
Utilities, Information, Finance and Insurance, Health Care and Social Assistance	22, 51, 52, 62	2%
Manufacturing; Wholesale Trade; Retail Trade; Professional, Scientific, and Technical Service; Management of Companies and Enterprises; Administrative and Support and Waste Management and Remediation Services; Educational Services; Health Care and Social Assistance; Public Administration	31-33, 42, 44-45, 54, 55, 56, 61, 92	5%

Agriculture, Forestry, Fishing, and Hunting; Mining; Construction; Transportation and Warehousing; Real Estate Rental and Leasing; Arts,
Entertainment, and Recreation;
Accommodation and Food Services;
Other Services (except Public Administration)
	11, 21, 23, 48-49, 53, 71, 72, 81	10%

As described by Table 20, a materiality threshold may be selected for an entity based on the entity's industry (e.g., as described by the entity's respective 2-digit NAICS code). For example, an entity having an NAICS code of 51 may have a selected materiality threshold of 2%. The materiality threshold and corresponding revenue value (e.g., based on the entity' annual gross revenue) for an entity may be used to determine an EP value from one or more of the generated EP curves for the entity. For example, for an entity with an NICS code of 31 and a gross annual revenue of 5,000,000 USD, a materiality threshold of 5% may produce a revenue value of 250,000 USD. Generated EP curves for the entity may be used to determine a probability (e.g., EP value) with which the entity's losses due to loss events may exceed the 250,000 USD threshold. Based on determining the probability, the probability may be mapped to the EP value thresholds described for either Option 1 or Option 2 in Table 13 to determine a risk factor score for the entity. Based on the selected materiality threshold, generated EP curves, and an entity's revenue value, a risk factor may be scored as described below.

In some embodiments, as described herein, one or more EP curves may be generated for an entity based on loss event types for selected event records used to generate the EP curves. An EP curve may be an uncalibrated EP curve that is based solely on the loss potential of the peer entity group for an entity under evaluation. An EP curve may be an outside-in calibrated EP curve that is based on scaling an uncalibrated EP curve by factoring in the entity's cyber security score using a completed outside-in assessment (e.g., where the assessment collects signals indicative of an entity's governance, fortitude, and threat factors externally to the entity's computing assets and networks). An EP curve may be an survey-input/self-attestation calibrated EP curve that is based on scaling the uncalibrated EP curve by the entity's self-attestation of their control posture using a completed survey-based assessment. The survey-input/self-attestation calibrated EP curve may be used when an entity has provided answers to survey questions and has not provided a full set of technical data from inside the entity. An EP curve may be an inside-out calibrated EP curve that is based on scaling an uncalibrated EP curve by factoring in the entity's cyber security score using a completed inside-out assessment (e.g., where the assessment only collects data for an entity's governance, fortitude, and threat factors internal and external to the entity's computing assets and networks). In order from least confidence to most confidence in expected losses, the EP curves may be ordered uncalibrated, outside-in calibrated, survey-input/self-attestation calibrated, and inside-out calibrated. The calibrated EP curves may illustrate the change in the probability that a certain level of loss will be exceeded given the entity's control state. This may increase or decrease the likelihood of exceeding losses at the materiality value relative to their peers.

In some embodiments, to generate EP curves as described herein, the cyber resilience assessment module **220** may generate datasets including event records for peer entity groups of an entity. The cyber resilience assessment module **220** may receive event records obtained by the data aggregation module **210** and may generate the datasets for each of the global, sector, region, cluster, and cohort peer entity groupings for an entity under evaluation. For each of the peer entity groups, the cyber resilience assessment module **220** may determine a number of available event records for each loss event type (e.g., loss event types including DD, BI, and FR loss event types). For each loss event type, the cyber resilience assessment module **220** may select a dataset of event records for a most granular of the peer entity groups that includes at least a minimum number (e.g., 10) of event records. As an example, the cyber resilience assessment module **220** may select datasets for the data disclosure and business interruption loss event types for the peer entity group at the cohort filtering level and may select a dataset for the fraud loss event type for the peer entity group at the cluster filtering level.

In some embodiments, based on selecting the dataset of event records for the most granular of the peer entity groups that includes at least a minimum number of event records for each loss event type, the cyber resilience assessment module **220** may generate an uncalibrated EP curve for each loss event type. To generate the uncalibrated EP curve, the cyber resilience assessment module may obtain and determine peer-group minimum, mode, maximum, and lambda values that summarize the loss values of the dataset of event records for each loss event type (e.g., loss event types including DD, BI, and FR loss event types). The minimum, maximum, and mode values for the range of loss values from the selected loss event records may be used to generate a beta PERT distribution, where the generated beta PERT distribution may be used as an input distribution from which to execute a number of Monte Carlo simulations (also referred to as "iterations"). The lambda value for the range of loss values from the selected loss event records may be a kurtosis value computed from the generated beta PERT distribution. Based on determining the minimum, mode, maximum, and lambda values for the loss values for each dataset, the cyber resilience assessment module **220** may execute a number of simulations (e.g., 50,000-500,000 simulations) of cyber events based on the input beta PERT distribution to determine expected loss values for each loss event type using Monte Carlo analysis (or another suitable simulation technique). For example, the cyber resilience assessment module **220** may execute 100,000 Monte Carlo simulations of cyber events to determine expected losses by the entity over an annual period. Monte Carlo analysis may be performed based on the minimum, mode, maximum, and/or lambda values determined from the loss values of the dataset of event records for each loss event type as described herein. Based on the Monte Carlo analysis and executed simulations of expected loss values for each loss event type, the cyber resilience assessment module **220** may obtain cyber loss simulation data that can be used to generate an uncalibrated EP curve for each loss event type indicative of the entity's loss potential and related probability of such loss potential. The cyber resilience assessment module **220** may generate an uncalibrated EP curve for each loss event type based on the cyber loss simulation data.

In some embodiments, the cyber resilience assessment module **220** may generate an outside-in calibrated EP curve for each loss event type. Generating the outside-in calibrated EP curve may be based on scaling the generated uncalibrated loss curve by factoring in the entity's cyber security score that can be based on assessment results for a completed outside-in cyber security assessment. The assessment results for the outside-in cyber security assessment may be included in the signals **112**. The method described below for generating the outside-in calibrated EP curve for each loss event type may be a formula for producing a single loss event (SLE) curve. To generate the outside-in calibrated EP curve, the cyber resilience assessment module **220** may derive a scaling value (e.g., a new mode value for generating a beta PERT distribution). To derive the scaling value, the cyber resilience assessment module **220** may obtain each of:

i. the entity's score for the detection and response subfactor referred to as "z_1" as determined based on an outside-in assessment

ii. the minimum possible score for the detection and response subfactor referred to as "p_1"

iii. the maximum possible score for the detection and response subfactor referred to as "p_2"

iv. the minimum loss value of the uncalibrated EP curve referred to as "q_{1i}", where "i" refers to each loss event type (e.g., i={DD, BI, FR})

v. the 75th quantile loss value of the uncalibrated EP curve referred to as "q_{2i}", where "i" refers to each loss event type (e.g., i={DD, BI, FR})

Based obtaining each of the above recited scores and values, the cyber resilience assessment module **220** may obtain an estimated mode value for each loss event type that is representative of the detection and response control strength of the respective uncalibrated EP curve for the loss event type. The estimated mode value for each loss event type (referred to as "i", where i={DD, BI, FR}) may be described by Equations 11a and 11b.

$$k_i=(q_{2i}-q_{1i})/(p_1-p_2) \tag{11a}$$

$$\text{New Mode Value}_i=(k_i \times z_1)+q_{2i} \tag{11b}$$

The minimum, maximum, and estimated new mode values for the range of loss values from the selected loss event records may be used to generate a beta PERT distribution, where the generated beta PERT distribution may be used as an input distribution from which to execute a number of Monte Carlo simulations. The lambda value for the range of loss values from the selected loss event records may be a kurtosis value computed from the generated beta PERT distribution.

Based on determining the estimated new mode value for each loss event type, the cyber resilience assessment module **220** may execute a number of simulations (e.g., 50,000-500,000 simulations) of cyber events based on the input beta PERT distribution (e.g., generated based on the estimated new mode value) to determine expected cyber losses for each loss event type using Monte Carlo analysis (or another suitable simulation technique). For example, the cyber resilience assessment module **220** may execute 100,000 Monte Carlo simulations of cyber events to determine expected losses by the entity over an annual period. Monte Carlo analysis may be performed based on the minimum, estimated new mode (e.g., as defined by Equation 11b), maximum, and/or lambda values determined from the loss values of the dataset of event records for each loss event type as described herein. Based on the Monte Carlo analysis and executed simulations of expected loss values for each loss event type, the cyber resilience assessment module **220** may obtain cyber loss simulation data that can be used to generate an outside-in calibrated EP curve for each loss event type indicative of the entity's loss potential and related probability of such loss potential. The cyber resilience assessment module **220** may generate an outside-in calibrated EP curve for each loss event type based on the cyber loss simulation data.

In some embodiments, the cyber resilience assessment module **220** may generate an inside-out calibrated EP curve for each loss event type. Generating the inside-out calibrated EP curve may be based on scaling the generated uncalibrated loss curve by factoring in the entity's cyber security score that can be based on assessment results for a completed inside-out cyber security assessment. The assessment results for the inside-out cyber security assessment may be included in the signals **112**. The method described below for generating the inside-out calibrated EP curve for each loss event type may be a formula for producing a single loss event (SLE) curve. To generate the inside-out calibrated EP curve, the cyber resilience assessment module **220** may derive a scaling value (e.g., a new mode value for generating a beta PERT distribution). To derive the scaling value, the cyber resilience assessment module **220** may obtain each of:

i. the entity's score for the detection and response subfactor referred to as "z_2" as determined based on an inside-out assessment

ii. the minimum possible score for the detection and response subfactor referred to as "p_1"

iii. the maximum possible score for the detection and response subfactor referred to as "p_2"

iv. the minimum loss value of the uncalibrated EP curve referred to as "q_{1_i}", where "i" refers to each loss event type (e.g., i={DD, BI, FR})

v. the 75th quantile loss value of the uncalibrated EP curve referred to as "q_{2_i}", where "i" refers to each loss event type (e.g., i={DD, BI, FR})

Based obtaining each of the above recited scores and values, the cyber resilience assessment module **220** may obtain an estimated mode value for each loss event type that is representative of the detection and response control strength of the respective uncalibrated EP curve for the loss event type The estimated mode value for each loss event type (referred to as "i", where i={DD, BI, FR}) may be described by Equations 12a and 12b.

$$k_i=(q_{2i}-q_{1i})/(p_1-p_2) \tag{12a}$$

$$\text{New Mode Value}_i=(k_i\times z_2)+q_{2i} \tag{12b}$$

The minimum, maximum, and estimated new mode values for the range of loss values from the selected loss event records may be used to generate a beta PERT distribution, where the generated beta PERT distribution may be used as an input distribution from which to execute a number of Monte Carlo simulations. The lambda value for the range of loss values from the selected loss event records may be a kurtosis value computed from the generated beta PERT distribution.

Based on determining the estimated new mode value for each loss event type, the cyber resilience assessment module **220** may execute a number of simulations (e.g., 50,000-500,000 simulations) of cyber events based on the input beta PERT distribution to determine expected loss values for each loss event type using Monte Carlo analysis (or another suitable simulation technique). For example, the cyber resilience assessment module **220** may execute 100,000 Monte Carlo simulations of cyber events to determine expected losses by the entity over an annual period. Monte Carlo analysis may be performed based on the minimum, estimated new mode (e.g., as defined by Equation 12b), maximum, and/or lambda values determined from the loss values of the dataset of event records for each loss event type as described herein. Based on the Monte Carlo analysis and executed simulations of expected loss values for each loss event type, the cyber resilience assessment module **220** may obtain cyber loss simulation data that can be used to generate an inside-out calibrated EP curve for each loss event type indicative of the entity's loss potential and related probability for the entity's loss potential. The cyber resilience assessment module **220** may generate an inside-out calibrated EP curve for each loss event type based on the cyber loss simulation data.

In some embodiments, based on determining cyber loss simulation data for each of the uncalibrated, outside-in calibrated, and inside-out calibrated EP curves, the cyber resilience assessment module **220** may obtain the cyber loss simulation data for the highest confidence type of EP curve. In order of lowest to highest confidence, the EP curves may be ordered as: uncalibrated EP curve, outside-in calibrated EP curve, and inside-out calibrated EP curve. Availability of outside-in and inside-out calibrated EP curves may be based on whether respective outside-in and inside-out assessment data is available to generate scores for a detection and response subfactor. Based on obtaining the cyber loss simulation data for the highest confidence type of EP curve, the cyber resilience assessment module **220** may determine an extreme value for the cyber loss simulation data for each loss event type, where the extreme value is an expected loss value that is one standard deviation away from a median expected loss value determined from the cyber loss simulation data. For example, the extreme value may be an expected loss value that is one standard deviation greater than a median expected loss value determined from the cyber loss simulation data. Based on determining the extreme value for each loss type, the cyber resilience assessment module **220** may determine a materiality value for the entity under evaluation, where the materiality value is equivalent to an entity's materiality threshold (e.g., as described with respect to the entity's industry in Table 20) multiplied by the entity's gross revenue (e.g., annual gross revenue). Based on determining the materiality value for the entity, the cyber resilience assessment module **220** may determine a materiality ratio for each loss type as described by Equations 13a, 13b, and 13c.

$$\text{Materiality } ratio_{BI}=\frac{Extreme_{BI}}{(\text{Materiality Value})} \tag{13a}$$

$$\text{Materiality } ratio_{DD}=\frac{Extreme_{DD}}{(\text{Materiality Value})} \tag{13b}$$

$$\text{Materiality } ratio_{FR}=\frac{Extreme_{FR}}{(\text{Materiality Value})} \tag{13c}$$

As shown by Equations 13a, 13b, and 13c, a materiality ratio may be determined for each of the BI, DD, and FR loss event types using the extreme value for each loss event type and the material value as described herein. From the determined materiality ratios for each loss event type, the cyber resilience assessment module **220** may identify and select the loss event type corresponding to a highest of the determined materiality ratios. For example, based on determining the fraud loss event type to have the highest of the materiality ratios, the cyber resilience assessment module may select the fraud loss event type.

In some embodiments, based on determining the loss event type corresponding to the highest of the determined materiality ratios, the cyber resilience assessment module **220** may generate an EP curve for the cyber loss simulation data corresponding to the highest confidence type of EP curve. To generate the EP curve, the cyber resilience assessment module **220** may obtain the cyber loss simulation data corresponding to the highest confidence type of EP curve. From the obtained cyber loss simulation data, the cyber resilience assessment module **220** may determine loss probabilities for a number of loss values. The cyber resilience assessment module **220** may generate the EP curve by plotting the determined loss probabilities on a y axis and the respective loss values on an x axis of a chart. The cyber resilience assessment module may plot a vertical line on the generated chart including the EP curve at value on the x axis corresponding to the determined materiality value for the entity. In some cases, the cyber resilience assessment module **220** may repeat each of the above-described steps for the remaining materiality ratios determined for the other respective loss event types to generate a respective EP curve for each of the loss event types.

In some embodiments, based on plotting a vertical line on the generated chart including the EP curve at value on the x axis corresponding to the determined materiality value for the entity, the cyber resilience assessment module **220** may determine the EP value at the y-axis intersect corresponding to the plotted materiality value, where the EP value corresponds to a probability that a loss value for the entity will exceed a value equivalent to the materiality value. In some cases, the cyber resilience assessment module **220** may determine an EP value for only the highest materiality ratio and respective selected loss event type. Based on determining the EP value for the entity, the cyber resilience assessment module **220** may determine a score for the risk factor based on the EP value thresholds and respective risk factor score corresponding to the determined EP value as defined by one of the rubrics (Option 1 or Option 2) in Table 13. As an example, for an EP value of 25%, for Option 1 as described in Table 13, the risk factor score for the entity may be 8. As another example, for an EP value of 48%, for Option 2 as described in Table 13, the risk factor score for the entity may be 4. The determined risk factor score may be used to determine a cyber resilience rating as described herein.

Exemplary Testing for Insurance and Capital Reserves

In some cases, the cyber risk assessment module **220** may perform exemplary testing for an entity's ability to withstand near worst case events. For an entity that has transferred risk to an insurer, the testing can include an analysis of the entity's relevant insurance policies. For an entity that is "self-insured" with capital reserves, the testing can include an analysis of the entity's capital reserve allocation inputs. In some cases, for entity with both insurance and "self-insurance", the testing can include analysis of both insurance and capital reserve allocation inputs.

To perform analysis and testing of the entity's ability to withstand near worst case events, the cyber resilience assessment module **220** may obtain the cyber loss simulation data corresponding to the highest confidence type of EP curve and respective generated EP curve for each loss event type. Based on the obtained data and EP curves, for each loss event type, the cyber resilience assessment module **220** may determine and select a loss value from the 95^{th} percentile of the respective EP curve. For each selected loss value, the cyber resilience assessment module **220** may deduct one or more of (i) the entity's applicable insurance coverages for the respective loss event type (e.g., after accounting for deductible/retention values); and (ii) any of the entity's capital reserves specifically earmarked for cyber losses. The entity's capital reserves may correspond to an amount of capital that was input into an allocation exercise and may not correspond to the computed output of capital allocation. The ratio of the loss value minus deductions relative to the materiality value previously determined for scoring of the risk factor subfactor may be used to determine a stress ratio for that loss event type. Equations 14a, 14b, and 14c describe stress ratio determination for each loss event type.

$$Stress_{DD} = \frac{DD_{95th} - \text{Insurance} - \text{Capital Reserves}}{(MT * \text{Gross Revenue})} \tag{14a}$$

-continued

$$Stress_{BI} = \frac{BI_{95th} - \text{Insurance} - \text{Capital Reserves}}{(MT * \text{Gross Revenue})} \tag{14b}$$

$$Stress_{FR} = \frac{FR_{95th} - \text{Insurance} - \text{Capital Reserves}}{(MT * \text{Gross Revenue})} \tag{14c}$$

Based on the determined stress ratios as determined by Equations 14a, 14b, and 14c, the cyber resilience assessment module **220** may determine and select a highest of the determined stress ratios. Using the highest stress ratio, a stress test subfactor may be scored as described by Table 21.

TABLE 21

Stress Test Subfactor Scoring Methodology

	Stress Test Subfactor Score			
Stress Test Evaluation	With Insurance and Reserves	With Insurance Only	With Reserves Only	With Neither
High x > 200%	2	1	1	0
Medium x > 100%	3	2	2	1
Low x < 100%	4	3	3	2

As shown in Table 21, the stress test subfactor may be score on a 0-4 scale, with 0 being the lowest (worst) possible score and 4 being the highest (best) possible score to evaluate an entity's ability to withstand near worst case events. The scoring may be based on whether the stress ratios determined for an entity included insurance coverages, capital reserves, or neither insurance coverages nor capital reserves. For example, an entity with a highest stress ratio of 105% that has only capital reserves and not insurance coverage may be assigned a stress test subfactor score of 2.

Exemplary Scoring for a Threat Factor

In some cases, the cyber risk assessment module **220** may generate a score for a threat factor. The threat factor may provide an indication of a relative amount of threat activity facing the entity compared to the entity's peers. An entity's threat activity and assessed score for a threat factor may be based on subfactors including a potential attack vector (e.g., measures of methods attackers can access an entity's computing systems and/or assets), malicious activity (e.g., measures of actual attacks on an entity's computing systems and/or assets), precursor attack data (e.g., threat activity against the entity's computing systems and/or assets, supply chain, and/or utilized services), and adversarial threats (e.g., which threat actors are targeting which industries) subfactor. Such subfactors as described herein can be encapsulated in a generated threat score. In some embodiments, the threat factor may be scored on a 0-100 scale and is evaluated according to a rubric for the subfactors (e.g., subfactors **106**) of the threat factor and respective capabilities (e.g., capabilities **108**) as shown in Table 22. Each of the subfactors may assess how prolific a conversation in the threat actor space is about an entity as compared to the entity's peers. The subfactors may assess an amount of precursor events to a specific cyber event (e.g., attach or incident) and subsequent incidents. In some cases, the threat factor may be measured and weighted using various gradients and scales different from those described in Table 22.

TABLE 22

Threat Factor Scoring Methodology

Subfactor	Capabilities	Total Points	Weight
Attack Vectors	Phishing Campaigns Extortion Attacker Requests for Help	0-100	25%
Malicious Activity	Compromised assets Suspicious traffic and anonymous activity Brand abuse Insider Threat	0-100	25%
Precursor Attack Data	Credentials Intellectual Property Customer Data Employees' Data Technical Information	0-100	25%
Adversarial Threats	Sophistication Level Attack Methods	0-100	25%

As shown in Table 22, in this particular embodiment, each of the subfactors (e.g., subfactors **106**) may be scored on a scale of 0-100, multiplied by a respective weight, and summed to produce a score for the governance factor as described by Equation 15.

$$\text{Threat Factor Score} = \sum_{x=1}^{4} Subfactor_x * Weight_x \tag{15}$$

In this particular embodiment, each subfactor may be weighted evenly. In other embodiments, the weights may be altered to address entity-specific and/or industry-specific needs. Each individual subfactor may be scored independently as described below. A score for each subfactor may represents a degree of the subfactor relative to the entity's peers or other industries.

In some embodiments, a threat factor may include an entity's potential attack vectors (referred to herein as "potential attack vectors") as a subfactor. An entity's potential attack vectors subfactor may measure an attacker's interest level, which can affect the likelihood of the potential attack vector being leveraged. The potential attack vectors subfactor may be representative of one or more the following areas of information in underground and dark web forums targeting the entity: (i) phishing campaigns, (ii) extortion campaigns, (iii) attacker requests for help, and (iv) recruitment attempts of insiders. The more potential attack vectors there are, the more the entity is at risk of a cyber incident. Accordingly, potential attack vectors subfactor may indicate both the interest level of threat-actors in targeting the entity the threat-actors' propensity for attack. A score for an entity's potential attack vectors subfactor may be based on one or more capabilities (e.g., capabilities **108**) and corresponding criteria. Examples of capabilities indicative of the potential attack vectors subfactor are described in Table 23.

TABLE 23

Potential Attack Vectors Subfactor Scoring Methodology

Potential Attack Vectors Capability	Criteria	Total Points	Weight
Phishing Campaigns	Measures activity indicating a possible phishing attack against the entity, based on underground web sources and network traffic analysis	0-100	25%
Extortion Campaigns	Measures activity indicating a possible extortion campaign against the entity, based on underground web sources	0-100	25%
Attacker requests for help	Measures of the amount of underground chatter of threat-actors' requesting help or information in the context of breaching/abusing the evaluated entity's assets	0-100	25%
Presence in Underground Sources	Measures the presence of the assessed entity in cyber related underground forums which are known as malicious and directly indicates threat-actors' malicious interests in the entity	0-100	25%

The potential attack vectors subfactor may be assessed by a number of indicators (e.g., indicators **110**) that quantify each of the capabilities described in Table 23. Indicators may be derived from signals (e.g., signals **112**) as described herein for the cyber resilience assessment tool **200**. In this particular embodiment, each of the capabilities may be scored on a scale of 0 to 100, multiplied by a respective weight, and then summed to produce a score for the potential attack vectors subfactor as described by Equation 16.

$$\text{Potential Attack Vectors Subfactor Score} = \sum_{x=1}^{4} Capability_x * Weight_x \tag{16}$$

In this particular embodiment, each capability may be weighted evenly. In other embodiments, the weights may be altered to address entity-specific and/or industry-specific needs. For example, weighting may be skewed toward one or more of the capabilities described in Table 23 based on the one or more capabilities being capabilities of interest.

In some embodiments, a threat factor may include malicious activity directed to an entity (referred to herein as "malicious activity") as a subfactor. An entity's malicious activity subfactor may measure actual events that are targeting an entity. The potential attack vectors subfactor may be representative of activity detected on the dark web, underground forums or other platforms covering one or more of: (i) compromised assets, (ii) suspicious traffic and anonymous activity, and (iii) brand abuse. The more potential attack vectors there are, the more the entity is at risk of a cyber incident. A score for an entity's malicious activity subfactor may be based on one or more capabilities (e.g., capabilities **108**) and corresponding criteria. Examples of capabilities indicative of the malicious activity subfactor are described in Table 24.

TABLE 24

Malicious Activity Subfactor Scoring Methodology

Malicious Activity Capability	Criteria	Total Points	Weight
Compromised Assets	Measures the amount of compromised assets in different time frames, analyzing the trend of it and comparing it to its cohort group.	0-100	25%

TABLE 24-continued

Malicious Activity Subfactor Scoring Methodology

Malicious Activity Capability	Criteria	Total Points	Weight
Malicious Network Traffic	Measures the amount/frequency of events that indicate that a malicious actor is abusing or comprising the assessed entity's assets, based on network traffic analysis.	0-100	25%
Brand Abuse	Measures the amount of brand abuse events that the entity suffered in a certain time frame, compared to the entity's cohort peer group.	0-100	25%
Insider Threat	Measures of the actual evidence of insider threats, based on dark web and underground sources.	0-100	25%

The malicious activity subfactor may be assessed by a number of indicators (e.g., indicators **110**) that quantify each of the capabilities described in Table 24. Indicators may be derived from signals (e.g., signals **112**) as described herein for the cyber resilience assessment tool **200**. Measurements of the compromised assets capability may be based on measurements from dark web and underground forums and blocklists. The malicious network traffic capability may measure protective Domain Name System (DNS) datasets and detects anomalies and suspicious communications between the assessed entity's assets and other external assets. Such analysis includes detecting communication between the assessed entity's assets and known command and control (C&C) servers, malware servers, spam services, bot services, and block-listed assets. The malicious network traffic capability may measure the assessed entity's response time to such events as compared to the entity's cohort peer group. The brand abuse capability may measure brand abuse events such as impersonation, defacements, and abused assets of the entity. Brand abuse events can harm the reputation of the entity and can potentially be a part of an attack-chain directed to the entity.

In this particular embodiment, each of the capabilities described in Table 24 may be scored on a scale of 0 to 100, multiplied by a respective weight, and then summed to produce a score for the malicious activity subfactor as described by Equation 17.

$$\text{Malicious Activity Subfactor Score} = \sum_{x=1}^{4} Capability_x * Weight_x \tag{17}$$

In this particular embodiment, each capability may be weighted evenly. In other embodiments, the weights may be altered to address entity-specific and/or industry-specific needs. For example, weighting may be skewed toward one or more of the capabilities described in Table 24 based on the one or more capabilities being capabilities of interest.

In some embodiments, a threat factor may include precursor attack data directed to an entity (referred to herein as "precursor attack data") as a subfactor. An entity's precursor attack data subfactor may measure an amount of exposed precursor attack data corresponding to the evaluated entity in a certain time frame as compared to the entity's cohort peer group. The precursor attack data subfactor may measure actual evidence of leaked information corresponding to the entity that is available on the dark web and in underground forums, such as leaked credentials, intellectual property, customer data, and technical specifications. Such leaked information may be a result of an attack on the evaluated entity and/or on affiliate(s) of the entity. Data leaks are often the result of past breaches of the entity's computing systems and/or assets, the entity's supply chain, and/or affiliates of the entity that have access to the entity's data. The greater the amount of an entity's data that is available on the Dark Web, the greater the entity's risk for a cyber incident. Malicious threat actors can leverage the entity's publicly exposed data to cause additional far-reaching effects, such as additional data breaches, system compromises, loss of brand reputation, and financial losses.

A score for an entity's precursor attack data subfactor may be based on one or more capabilities (e.g., capabilities **108**) and corresponding criteria. Examples of capabilities indicative of the precursor attack data subfactor are described in Table 25.

TABLE 25

Precursor Attack Data Subfactor Scoring Methodology

Precursor Attack Data Capability	Criteria	Total Points	Weight
Leaked Credentials	Availability of entity's credentials (purported or real)	0-100	20%
Leaked Intellectual Property	Availability of intellectual property from the entity	0-100	20%
Leaked Customer Data	Customer data purported to be exfiltrated from the entity	0-100	20%
Leaked Technical Specifications	Information about an entity's technological infrastructure	0-100	20%
Leaked Employees' Data	Employees' personal data which can be used by threat-actors for further malicious activities	0-100	20%

The precursor attack data subfactor may be assessed by a number of indicators (e.g., indicators **110**) that quantify each of the capabilities described in Table 25. Indicators may be derived from signals (e.g., signals **112**) as described herein for the cyber resilience assessment tool **200**. In this particular embodiment, each of the capabilities described in Table 25 may be scored on a scale of 0 to 100, multiplied by a respective weight, and then summed to produce a score for the precursor attack data subfactor as described by Equation 18.

$$\text{Precursor Attack Data Subfactor Score} = \sum_{x=1}^{5} Capability_x * Weight_x \tag{18}$$

In this particular embodiment, each capability may be weighted evenly. In other embodiments, the weights may be altered to address entity-specific and/or industry-specific needs. For example, weighting may be skewed toward one or more of the capabilities described in Table 25 based on the one or more capabilities being capabilities of interest.

In some embodiments, a threat factor may include adversarial threats directed to an entity (referred to herein as "adversarial threats") as a subfactor. An entity's adversarial threats subfactor may measure the adversarial threats that are most threatening to the evaluated entity's industry. The measurement may be derived from segmentation of threat actors' capability level of the threat groups. As an example, for a threat group corresponding to nation state attackers, the threat group may have a threat capability of between 95% and 99%.

A score for an entity's adversarial threats subfactor may be based on one or more capabilities (e.g., capabilities **108**) and corresponding criteria. An example capability indicative of the adversarial threats subfactor is described in Table 26.

TABLE 26

Adversarial Threats Subfactor Scoring Methodology

Adversarial Threats Capability	Criteria	Total Points	Weight
Sophistication Level	The sophisticated level of the attacker is determined by the tactics, techniques, and procedures (TTPs) they use as well as their national origin and affiliation (cybercrime, state-sponsored, nation-state). The sophistication level assessed by three levels: High, Medium, and Low.	0-100	20%

The adversarial threats subfactor may be assessed by a number of indicators (e.g., indicators **110**) that quantify the capability described in Table 26. Indicators may be derived from signals (e.g., signals **112**) as described herein for the cyber resilience assessment tool **200**. In this particular embodiment, the capability described in Table 26 may be scored on a scale of 0 to 100 to produce a score for the adversarial threats subfactor.

Exemplary Scoring for a Cyber Resilience Rating

In some embodiments, the cyber resilience assessment module **220** of the cyber resilience assessment tool may determine a cyber resilience rating based on the governance, fortitude, and risk factors corresponding to respective governance, fortitude, and risk postures of an entity. The cyber resilience rating ranking scale as described in Table 27 may be representative of how often a rated entity is expected to experience material cyber events as compared to other entities.

TABLE 27

Cyber Resilience Rating Rankings

Position	Rating
Leaders	CR1 CR2
Average	CR3 CR4 CR5
Laggards	CR6 CR7 CR8

As described by Table 27, identifiers CR1 to CR8 may be representative of cyber resilience ratings for an entity in order of a highest rating to a lowest rating. The identifiers may correspond to a respective position indicative of where the entity corresponding to the identifier and cyber resilience rating is ranked among other entities with respect to cyber resilience. For example, entities having cyber resilience ratings corresponding to the identifiers CR1 and CR2 may be leaders among entities with respect to cyber resilience, while entities having cyber resilience ratings corresponding to the identifiers CR6, CR7, and CR8 may be laggards among entities with respect to cyber resilience.

In some embodiments, the cyber resilience rating can include the scores of the combined fortitude and governance factors plotted against the score of the risk factor, where a respective cyber resilience rating may be determined for each of a number of scoring methods. In some cases, the cyber resilience rating may be scored using a scoring method based on an EP value and materiality value (e.g., as described with respect to scoring for the risk factor). In some cases, a scoring rubric may use the number of scoring methods to determine applicability of each scoring method to real world assessments. For example, there can be a relationship between the fours factors (risk, threat, fortitude, and governance) described herein, such that the combination of scores for the fortitude and governance factor can be represented as a cyber security score. In some cases, the cyber security score can be plotted against the risk score in an (x, y) pair to determine the cyber resilience rating for the entity.

In some embodiments, a multiplicative scoring method may be used by the cyber resilience assessment module **220** to determine a cyber resilience rating for an entity. For the multiplicative scoring method, the cyber resilience assessment module **220** may multiply the fortitude and governance factor scores to determine a combined score. The cyber resilience assessment module **220** may multiply the combined score by a scaled risk factor score as described by Equation 19.

$$CRx\text{ Score} = \frac{\text{Fortitude Score} + \text{Goverance Score}}{2} * (\text{Risk Score} * 10) \tag{19}$$

The multiplicative scoring method performed by the cyber resilience assessment module **220** may yield approximate cyber resilience scores as described by Table 28.

TABLE 28

Cyber Resilience Rating For Multiplicative Scoring Method

Combined Fortitude and Governance Scores Minimum	Cyber Resilience Rating									
901	90	180	270	360	451	541	631	721	811	901
801	80	160	240	320	401	481	561	641	721	801
701	70	140	210	280	351	421	491	561	631	701
601	60	120	180	240	301	361	421	481	541	601

TABLE 28-continued

Cyber Resilience Rating For Multiplicative Scoring Method

Combined Fortitude and Governance Scores Minimum	Cyber Resilience Rating									
501	50	100	150	200	251	301	351	401	451	501
401	40	80	120	160	201	241	281	321	361	401
301	30	60	90	120	151	181	211	241	271	301
201	20	40	60	80	101	121	141	161	181	201
101	10	20	30	40	51	61	71	81	91	101
1	0	0	0	0	1	1	1	1	1	1
	1	2	3	4	5	6	7	8	9	10
	Risk Score									

The cyber resilience rating ranking scale for the multiplicative scoring method as described in Table 29 may be representative of how often a rated entity is expected to experience material cyber events as compared to other entities.

TABLE 29

Cyber Resilience Rating Rankings for Multiplicative Scoring Method

Position	Rating	Score Min	Score Max
Leaders	CR1	801	1000
	CR2	701	800

TABLE 29-continued

Cyber Resilience Rating Rankings for Multiplicative Scoring Method

Position	Rating	Score Min	Score Max
Average	CR3	601	700
	CR4	501	600
	CR5	401	500
Laggards	CR6	301	400
	CR7	201	300
	CR8	0	200

In some embodiments, an averaging scoring method may be used by the cyber resilience assessment module **220** to determine a cyber resilience rating for an entity. For the averaging scoring method, the cyber resilience assessment module **220** may multiply the fortitude and governance factor scores to determine a combined score. The cyber resilience assessment module **220** may multiply the combined score by a scaled risk factor score as described by Equation 20.

$$CRx\text{ Score} = \frac{(\text{Fortitude Score} + \text{Goverance Score} + (\text{Risk Score} * 10)) * 100)}{3} \qquad (20)$$

The averaging scoring method performed by the cyber resilience assessment module **220** may yield approximate cyber resilience scores as described by Table 30.

TABLE 30

Cyber Resilience Rating For Averaging Scoring Method

Combined Fortitude and Governance Scores											
Min	Max	Cyber Resilience Rating									
901	1000	501	551	601	651	701	751	801	851	901	951
801	900	451	501	551	601	651	701	751	801	851	901
701	800	401	451	501	551	601	651	701	751	801	851
601	700	351	401	451	501	551	601	651	701	751	801
501	600	301	351	401	451	501	551	601	651	701	751
401	500	251	301	351	401	451	501	551	601	651	701
301	400	201	251	301	351	401	451	501	551	601	651
201	300	151	201	251	301	351	401	451	501	551	601
101	200	101	151	201	251	301	351	401	451	501	551
1	100	51	101	151	201	251	301	351	401	451	501
		1	2	3	4	5	6	7	8	9	10
		Risk Score									

The cyber resilience rating ranking scale for the averaging scoring method as described in Table 31 may be representative of how often a rated entity is expected to experience material cyber events as compared to other entities.

TABLE 31

Cyber Resilience Rating Rankings for Averaging Scoring Method

Position	Rating	Cyber Resilience Rating Minimum	Cyber Resilience Rating Maximum
Leaders	CR1	901	1000
	CR2	801	900

TABLE 31-continued

Cyber Resilience Rating Rankings for Averaging Scoring Method

Position	Rating	Cyber Resilience Rating Minimum	Cyber Resilience Rating Maximum
Average	CR3	701	800
	CR4	601	700
	CR5	501	600
Laggards	CR6	401	500
	CR7	301	400
	CR8	0	300

In some embodiments, a quadrant scoring method may be used by the cyber resilience assessment module **220** to determine a cyber resilience rating for an entity. For the quadrant scoring method, the cyber resilience assessment module **220** may multiply the fortitude and governance factor scores to determine a combined score. The combined score and the risk factor score may be input to Tables 32 and 33 to determine the cyber resilience rating for an entity.

TABLE 32

Cyber Resilience Rating For Averaging Scoring Method

Combined Fortitude and Governance Scores					
Min	Max	Cyber Resilience Rating			
901	1000	CR6	CR5	CR2	CR1
801	900				
701	800				
601	700	CR7	CR4	CR3	CR2
501	600				
401	500		CR6	CR4	CR5
301	400				
201	300	CR8	CR7		CR6
101	200				
1	100				
		1 2 3 4 5 6 7 8 9 10 Risk			

The cyber resilience rating ranking scale for the multiplicate scoring method as described in Table 33 may be representative of how often a rated entity is expected to experience material cyber events as compared to other entities.

TABLE 33

Cyber Resilience Rating Rankings for Quadrant Scoring Method

Position	Rating	Combined Fortitude and Governance Score	Risk Score
Leaders	CR1	701-1000	8-10
	CR2	701-1000	6-8
		501-700	8-10
Average	CR3	501-700	6-8
	CR4	501-700	4-6
		301-500	6-8
	CR5	701-1000	4-6
		301-500	8-10
		701-1000	1-3
	CR6	301-500	4-6
		1-300	8-10
Laggards	CR7	301-700	1-3
		1-300	4-7
	CR8	1-300	1-3

In some embodiments, a materiality scoring method may be used by the cyber resilience assessment module **220** to determine a cyber resilience rating for an entity. For the quadrant scoring method, the cyber resilience assessment module **220** may determine an intersection of an entity's materiality value with a selected EP curve and may identify and select the EP value corresponding to the intersection. The cyber resilience assessment module **220** may input to the EP value to the scoring methodology described in Table 34 to determine a cyber resilience score.

TABLE 34

Cyber Resilience Rating Rankings For Materiality Scoring Method

Position	Rating	EP Materiality Intersect Value
Leaders	CR1	>0.0% to <0.6%
	CR2	>0.5% to <1.1%
Average	CR3	>1.0% to <3.1%
	CR4	>3.0% to <6.1%
	CR5	>6.0% to <10.1%
Laggards	CR6	>10.0% to <15.1%
	CR7	>15.0% to <25.1%
	CR8	>25.0%

The materiality scoring method can be conducted with an L2, L3, and/or L4 EP curve, individually or in any combination. The materiality scoring method may not be conducted with an L1 EP curve (uncalibrated EP curve) based on the L1 EP curve not including the control strength represented by the fortitude and governance factors.

In some embodiments, cyber security score may be computed out of 1,000 possible points with each rating distributed as described in Table 35:

TABLE 35

Exemplary Ratings for a Cyber Security Score

Score Range	Expected Industry Performance (80% of entities in these industries are expected to perform in this range)
700-1,000	Utilities Information Finance and Insurance Health Care and Social Assistance
350-850	Manufacturing Wholesale Trade Retail Trade Professional, Scientific, and Technical Services Management of Companies and Enterprises Administrative and Support and Waste Management and Remediation Services Educational Services Health Care and Social Assistance Public Administration
251-400	Agriculture, Forestry, Fishing and Hunting Mining Construction Transportation and Warehousing Real Estate Rental and Leasing Arts, Entertainment, and Recreation Accommodation and Food Services Other Services
0-250	Cyber Poverty Line Entities scored in this range are insufficient to defend against even the most basic cyber attacks

The cyber security score may be a measure of the approach and actions of an assessed entity associated with the security processes and technology to protect confidentiality, integrity, and availability of the entity's data and assets to a degree commensurate with the level of threat to which the entity is exposed. A cyber security score may be determined based on a sum of the scores for the fortitude and governance factors multiplied by 5, as described by Equation 21.

$$\text{Cyber Security Score}=(\text{Fortitude Score}+\text{Governance Score})*5 \tag{21}$$

The approach and actions of an assessed entity may include security governance, policies, technologies, tools, and training that can be used to provide the best-possible protection for the state of the entity's cyber environment and the entity's users.

Exemplary Method for Determining a Cyber Resilience Rating

In some embodiments, the cyber resilience assessment tool **200** may provide assessments of an entity's cyber resilience. To assess an entity's cyber resilience, the cyber resilience assessment tool **200** may perform a method to determine a cyber resilience rating indicative of the entity's cyber resilience, where the cyber resilience rating is based on scoring for governance, fortitude, and/or risk factors as described herein. Referring to FIG. **3**, a flowchart of an exemplary method **300** for providing a cyber resilience rating for an entity is depicted. The method **300** may be suitable for generating respective scores for governance, fortitude, and risk factors. One of ordinary skill in the art will appreciate that the method **300** may be executed by the cyber resilience rating more than once (e.g., periodically) for a particular entity to evaluate changes in an entity's cyber resilience rating and/or individual scores of factors and/or subfactors included in the entity's cyber resilience rating.

At step **302**, the cyber resilience assessment tool **200** may obtain and/or otherwise receive a number of entity indicators corresponding to a number of entities. Each the entity indicators may include characteristic information for a respective entity of the entities. Each of the number of entities may have and/or otherwise correspond to a respective entity indicator of the number of entity indicators, such that the cyber resilience assessment tool **200** receives characteristic information for each of the entities. The characteristic information for a respective entity may include indicators providing information for the entity's industry, geographic location, and/or size as described herein. The entity indicators may be received by one or more computing systems (e.g., external computing systems) that are communicatively connected to the cyber resilience assessment tool **200**.

At step **304**, the cyber resilience assessment tool **200** may determine one or more peer groups for an entity based on the peer group analysis techniques described herein. In some cases, the cyber resilience assessment tool **200** may determine a peer group for the entity based on the respective characteristic information (e.g., industry, geography, size) of the entity relative to a number of entities, where the peer group includes a subset of the plurality of entities.

At step **306**, the cyber resilience assessment tool **200** may obtain a number of loss event records for each of the peer groups. Each loss event record may include a respective loss value and may correspond to a cyber event associated with a respective entity of the peer group. The loss event records corresponding to each peer group may be categorized as corresponding to respective groups of loss event records selected from the number of loss event records. A group of loss event records from the groups of loss event records for each peer group may correspond to a data disclosure type. A group of loss event records from the groups of loss event records for each peer group may correspond to a business interruption type. A group of loss event records from the groups of loss event records for each peer group may correspond to a fraud type. Loss event records may be grouped based on the loss event records corresponding to one of the data disclosure type, business interruption type, or fraud type.

At step **308**, the cyber resilience assessment tool **200** may execute a number of Monte Carlo simulations to generate respective loss simulation data for each group of loss event records. Groups of loss event records may correspond to the data disclosure type, business interruption type, and fraud type. A minimum number of loss event records included in a group of loss event records may be required to execute the Monte Carlo simulations. If a group of loss event records for a peer group does not included a minimum number of loss event records, the cyber resilience assessment tool **200** may use the group of event records for a less granular peer group for the entity. The cyber resilience assessment tool **200** may repeatedly attempt to use the group of event records for a less granular peer group of the entity for execution of the Monte Carlo simulations until the number of event records included in the group of event records meets the minimum number of loss event records. The cyber resilience assessment tool **200** may initially attempt to use the group of event records for the most granular peer group of the entity for execution of the Monte Carlo simulations. The Monte Carlo simulations may be executed based on the loss values of the loss event records of the respective group of loss event records. For example, the Monte Carlo simulations may be executed based on statistics aggregated from the loss values of the loss event records of the respective group of loss event records, where the statistics are used to generate beta PERT distributions that are provided as inputs for the Monte Carlo simulations. In some cases, the Monte Carlo simulations may be executed based on inside-out or outside-in assessment results for the entity.

At step **310**, the cyber resilience assessment tool **200** may identify, based on the respective loss simulation data for each group of loss event records, an expected probability value corresponding to a materiality loss value of the entity. The materiality loss value for the entity may be based on the entity's revenue and industry as described herein. Based on the materiality loss value, the cyber resilience assessment tool **200** may determining materiality ratios for the simulation loss data corresponding to each group of loss event records (e.g., corresponding to the data disclosure type, business interruption type, and fraud type). The cyber resilience assessment tool **200** may select the loss simulation data of the group of event records corresponding to the high of the determined materiality ratios. The cyber resilience assessment tool **200** may generate one or more EP curves from the selected loss simulation data. The EP curves may any of the type of EP curves described herein based on an availability of assessment results. The cyber resilience assessment tool **200** may select an EP curve having the highest confidence from the generated EP curves and may identify the expected probability value from the selected EP curve that corresponds to the materiality value for the entity.

At step **312**, the cyber resilience assessment tool **200** may provide a risk factor score indicative of a cyber security risk of the entity based on the identified expected probability value. The cyber resilience assessment tool **200** may determine the risk factor score based on any of the risk factor scoring techniques described herein that are based on the expected probability value of the entity.

At step **314**, the cyber resilience assessment tool **200** may provide a cyber resilience rating for the entity based on a combination of the risk factor score, a fortitude factor score, and a governance factor score. The cyber resilience assessment tool **200** may provide the cyber resilience rating for the entity based on any of the suitable rating techniques described herein. The cyber resilience rating and the scores for the governance, fortitude, and/or risk factors may be made available via a graphical user interface with information indicative of the subfactors contributing each of the scores.

Computer-Based Implementations

In some examples, some or all of the processing described above can be carried out on a personal computing device, on one or more centralized computing devices, or via cloud-based processing by one or more servers. In some examples, some types of processing occur on one device and other types of processing occur on another device. In some examples, some or all of the data described above can be stored on a personal computing device, in data storage hosted on one or more centralized computing devices, or via cloud-based storage. In some examples, some data are stored in one location and other data are stored in another location. In some examples, quantum computing can be used. In some examples, functional programming languages can be used. In some examples, electrical memory, such as flash-based memory, can be used.

FIG. **4** is a block diagram of an example computer system **400** that may be used in implementing the technology described in this document. General-purpose computers, network appliances, mobile devices, or other electronic systems may also include at least portions of the system **400**. The system **400** includes a processor **410**, a memory **420**, a storage device **430**, and an input/output device **440**. Each of the components **410**, **420**, **430**, and **440** may be interconnected, for example, using a system bus **450**. The processor **410** is capable of processing instructions for execution within the system **400**. In some implementations, the processor **410** is a single-threaded processor. In some implementations, the processor **410** is a multi-threaded processor. The processor **410** is capable of processing instructions stored in the memory **420** or on the storage device **430**.

The memory **420** stores information within the system **400**. In some implementations, the memory **420** is a non-transitory computer-readable medium. In some implementations, the memory **420** is a volatile memory unit. In some implementations, the memory **420** is a nonvolatile memory unit.

The storage device **430** is capable of providing mass storage for the system **400**. In some implementations, the storage device **430** is a non-transitory computer-readable medium. In various different implementations, the storage device **430** may include, for example, a hard disk device, an optical disk device, a solid-date drive, a flash drive, or some other large capacity storage device. For example, the storage device may store long-term data (e.g., database data, file system data, etc.). The input/output device **440** provides input/output operations for the system **400**. In some implementations, the input/output device **440** may include one or more of a network interface devices, e.g., an Ethernet card, a serial communication device, e.g., an RS-232 port, and/or a wireless interface device, e.g., an 802.11 card, a 3G wireless modem, or a 4G wireless modem. In some implementations, the input/output device may include driver devices configured to receive input data and send output data to other input/output devices, e.g., keyboard, printer and display devices **460**. In some examples, mobile computing devices, mobile communication devices, and other devices may be used.

In some implementations, at least a portion of the approaches described above may be realized by instructions that upon execution cause one or more processing devices to carry out the processes and functions described above. Such instructions may include, for example, interpreted instructions such as script instructions, or executable code, or other instructions stored in a non-transitory computer readable medium. The storage device **430** may be implemented in a distributed way over a network, such as a server farm or a set of widely distributed servers, or may be implemented in a single computing device.

Although an example processing system has been described in FIG. **4**, embodiments of the subject matter, functional operations and processes described in this specification can be implemented in other types of digital electronic circuitry, in tangibly-embodied computer software or firmware, in computer hardware, including the structures disclosed in this specification and their structural equivalents, or in combinations of one or more of them. Embodiments of the subject matter described in this specification can be implemented as one or more computer programs, i.e., one or more modules of computer program instructions encoded on a tangible nonvolatile program carrier for execution by, or to control the operation of, data processing apparatus. Alternatively or in addition, the program instructions can be encoded on an artificially generated propagated signal, e.g., a machine-generated electrical, optical, or electromagnetic signal that is generated to encode information for transmission to suitable receiver apparatus for execution by a data processing apparatus. The computer storage medium can be a machine-readable storage device, a machine-readable storage substrate, a random or serial access memory device, or a combination of one or more of them.

The term "system" may encompass all kinds of apparatus, devices, and machines for processing data, including by way of example a programmable processor, a computer, or multiple processors or computers. A processing system may include special purpose logic circuitry, e.g., an FPGA (field programmable gate array) or an ASIC (application specific integrated circuit). A processing system may include, in addition to hardware, code that creates an execution environment for the computer program in question, e.g., code that constitutes processor firmware, a protocol stack, a database management system, an operating system, or a combination of one or more of them.

A computer program (which may also be referred to or described as a program, software, a software application, a module, a software module, a script, or code) can be written in any form of programming language, including compiled or interpreted languages, or declarative or procedural languages, and it can be deployed in any form, including as a standalone program or as a module, component, subroutine, or other unit suitable for use in a computing environment. A computer program may, but need not, correspond to a file in a file system. A program can be stored in a portion of a file that holds other programs or data (e.g., one or more scripts stored in a markup language document), in a single file dedicated to the program in question, or in multiple coordinated files (e.g., files that store one or more modules, sub programs, or portions of code). A computer program can be deployed to be executed on one computer or on multiple computers that are located at one site or distributed across multiple sites and interconnected by a communication network.

The processes and logic flows described in this specification can be performed by one or more programmable computers executing one or more computer programs to perform functions by operating on input data and generating output. The processes and logic flows can also be performed by, and apparatus can also be implemented as, special purpose logic circuitry, e.g., an FPGA (field programmable gate array) or an ASIC (application specific integrated circuit).

Computers suitable for the execution of a computer program can include, by way of example, general or special purpose microprocessors or both, or any other kind of central processing unit. Generally, a central processing unit will receive instructions and data from a read-only memory or a random access memory or both. A computer generally includes a central processing unit for performing or executing instructions and one or more memory devices for storing instructions and data. Generally, a computer will also include, or be operatively coupled to receive data from or transfer data to, or both, one or more mass storage devices for storing data, e.g., magnetic, magneto optical disks, or optical disks. However, a computer need not have such devices. Moreover, a computer can be embedded in another device, e.g., a mobile telephone, a personal digital assistant (PDA), a mobile audio or video player, a game console, a Global Positioning System (GPS) receiver, or a portable storage device (e.g., a universal serial bus (USB) flash drive), to name just a few.

Computer readable media suitable for storing computer program instructions and data include all forms of nonvolatile memory, media and memory devices, including by way of example semiconductor memory devices, e.g., EPROM, EEPROM, and flash memory devices; magnetic disks, e.g., internal hard disks or removable disks; magneto optical disks; and CD-ROM and DVD-ROM disks. The processor and the memory can be supplemented by, or incorporated in, special purpose logic circuitry.

To provide for interaction with a user, embodiments of the subject matter described in this specification can be implemented on a computer having a display device, e.g., a CRT (cathode ray tube) or LCD (liquid crystal display) monitor, for displaying information to the user and a keyboard and a pointing device, e.g., a mouse or a trackball, by which the user can provide input to the computer. Other kinds of devices can be used to provide for interaction with a user as well; for example, feedback provided to the user can be any form of sensory feedback, e.g., visual feedback, auditory feedback, or tactile feedback; and input from the user can be received in any form, including acoustic, speech, or tactile input. In addition, a computer can interact with a user by sending documents to and receiving documents from a device that is used by the user; for example, by sending web pages to a web browser on a user's user device in response to requests received from the web browser.

Embodiments of the subject matter described in this specification can be implemented in a computing system that includes a back end component, e.g., as a data server, or that includes a middleware component, e.g., an application server, or that includes a front end component, e.g., a client computer having a graphical user interface or a Web browser through which a user can interact with an implementation of the subject matter described in this specification, or any combination of one or more such back end, middleware, or front end components. The components of the system can be interconnected by any form or medium of digital data communication, e.g., a communication network. Examples of communication networks include a local area network ("LAN") and a wide area network ("WAN"), e.g., the Internet.

The computing system can include clients and servers. A client and server are generally remote from each other and typically interact through a communication network. The relationship of client and server arises by virtue of computer programs running on the respective computers and having a client-server relationship to each other.

While this specification contains many specific implementation details, these should not be construed as limitations on the scope of what may be claimed, but rather as descriptions of features that may be specific to particular embodiments. Certain features that are described in this specification in the context of separate embodiments can also be implemented in combination in a single embodiment. Conversely, various features that are described in the context of a single embodiment can also be implemented in multiple embodiments separately or in any suitable subcombination. Moreover, although features may be described above as acting in certain combinations and even initially claimed as such, one or more features from a claimed combination can in some cases be excised from the combination, and the claimed combination may be directed to a sub-combination or variation of a sub-combination.

Similarly, while operations are depicted in the drawings in a particular order, this should not be understood as requiring that such operations be performed in the particular order shown or in sequential order, or that all illustrated operations be performed, to achieve desirable results. In certain circumstances, multitasking and parallel processing may be advantageous. Moreover, the separation of various system components in the embodiments described above should not be understood as requiring such separation in all embodiments, and it should be understood that the described program components and systems can generally be integrated together in a single software product or packaged into multiple software products.

Particular embodiments of the subject matter have been described. Other embodiments are within the scope of the following claims. For example, the actions recited in the claims can be performed in a different order and still achieve desirable results. As one example, the processes depicted in the accompanying figures do not necessarily require the particular order shown, or sequential order, to achieve desirable results. In certain implementations, multitasking and parallel processing may be advantageous. Other steps or stages may be provided, or steps or stages may be eliminated, from the described processes. Accordingly, other implementations are within the scope of the following claims.

Terminology

The phraseology and terminology used herein is for the purpose of description and should not be regarded as limiting.

The term "approximately", the phrase "approximately equal to", and other similar phrases, as used in the specification and the claims (e.g., "X has a value of approximately Y" or "X is approximately equal to Y"), should be understood to mean that one value (X) is within a predetermined range of another value (Y). The predetermined range may be plus or minus 20%, 10%, 5%, 3%, 1%, 0.1%, or less than 0.1%, unless otherwise indicated.

The indefinite articles "a" and "an," as used in the specification and in the claims, unless clearly indicated to the contrary, should be understood to mean "at least one." The phrase "and/or," as used in the specification and in the claims, should be understood to mean "either or both" of the elements so conjoined, i.e., elements that are conjunctively present in some cases and disjunctively present in other cases. Multiple elements listed with "and/or" should be construed in the same fashion, i.e., "one or more" of the elements so conjoined. Other elements may optionally be present other than the elements specifically identified by the "and/or" clause, whether related or unrelated to those elements specifically identified. Thus, as a non-limiting example, a reference to "A and/or B", when used in conjunction with open-ended language such as "comprising" can refer, in one embodiment, to A only (optionally including elements other than B); in another embodiment, to B only (optionally including elements other than A); in yet another embodiment, to both A and B (optionally including other elements); etc.

As used in the specification and in the claims, "or" should be understood to have the same meaning as "and/or" as defined above. For example, when separating items in a list, "or" or "and/or" shall be interpreted as being inclusive, i.e., the inclusion of at least one, but also including more than one, of a number or list of elements, and, optionally, additional unlisted items. Only terms clearly indicated to the contrary, such as "only one of" or "exactly one of," or, when used in the claims, "consisting of," will refer to the inclusion of exactly one element of a number or list of elements. In general, the term "or" as used shall only be interpreted as indicating exclusive alternatives (i.e. "one or the other but not both") when preceded by terms of exclusivity, such as "either," "one of," "only one of," or "exactly one of." "Consisting essentially of," when used in the claims, shall have its ordinary meaning as used in the field of patent law.

As used in the specification and in the claims, the phrase "at least one," in reference to a list of one or more elements, should be understood to mean at least one element selected from any one or more of the elements in the list of elements, but not necessarily including at least one of each and every element specifically listed within the list of elements and not excluding any combinations of elements in the list of elements. This definition also allows that elements may optionally be present other than the elements specifically identified within the list of elements to which the phrase "at least one" refers, whether related or unrelated to those elements specifically identified. Thus, as a non-limiting example, "at least one of A and B" (or, equivalently, "at least one of A or B," or, equivalently "at least one of A and/or B") can refer, in one embodiment, to at least one, optionally including more than one, A, with no B present (and optionally including elements other than B); in another embodiment, to at least one, optionally including more than one, B, with no A present (and optionally including elements other than A); in yet another embodiment, to at least one, optionally including more than one, A, and at least one, optionally including more than one, B (and optionally including other elements); etc.

The use of "including," "comprising," "having," "containing," "involving," and variations thereof, is meant to encompass the items listed thereafter and additional items.

Use of ordinal terms such as "first," "second," "third," etc., in the claims to modify a claim element does not by itself connote any priority, precedence, or order of one claim element over another or the temporal order in which acts of a method are performed. Ordinal terms are used merely as labels to distinguish one claim element having a certain name from another element having a same name (but for use of the ordinal term), to distinguish the claim elements.

What is claimed is:

1. A computer-implemented method for providing a cyber resilience rating for an entity of a plurality of entities, the method comprising:

obtaining a plurality of entity indicators corresponding to the plurality of entities, wherein each of the plurality of entity indicators comprises characteristic information for a respective entity of the plurality of entities, and wherein each of the plurality of entities corresponds to a respective entity indicator of the plurality of entity indicators;

determining a peer group for the entity based on the respective characteristic information for the entity, wherein the peer group comprises a subset of the plurality of entities;

obtaining a plurality of loss event records for the peer group, wherein each loss event record comprises a respective loss value and corresponds to a cyber event associated with a respective entity of the peer group, wherein respective groups of loss event records selected from the plurality of loss event records correspond to a data disclosure type, a business interruption type, and a fraud type;

executing, for each group of loss event records, a plurality of Monte Carlo simulations to generate respective loss simulation data based on the respective loss values of the loss event records included in the group and results for a cyber security assessment of the entity;

identifying, based on the respective loss simulation data for each group of loss event records, an expected probability value corresponding to a materiality loss value of the entity;

providing a risk factor score indicative of a cyber security risk of the entity based on the identified expected probability value; and

providing a cyber resilience rating for the entity based on a combination of the risk factor score, a fortitude factor score, and a governance factor score, wherein the fortitude factor score is indicative of a cyber security control posture of the entity, and wherein the governance factor score is indicative of an administration of cyber security controls by the entity.

2. The method of claim **1**, wherein the characteristic information comprises an industry indicator, a geography indicator, and a size indicator for the respective entity.

3. The method of claim **2**, wherein the determining the peer group for the entity based on the respective entity characteristics of the entity further comprises:

selecting, from the plurality of entities, the subset of the plurality of entities for inclusion in the peer group based on the respective characteristic information corresponding to each entity of the subset of the plurality of entities comprising at least one of: the industry indicator, the geography indicator, and the size indicator corresponding to the entity.

4. The method of claim **1**, wherein the peer group comprises a first peer group and a second peer group, wherein the first peer group and the second peer group comprise different subsets of the plurality of entities.

5. The method of claim **1**, wherein each loss event record of the plurality of loss event records comprises a respective loss event type corresponding to one of: the data disclosure type, the business interruption type, or the fraud type, and further comprising:

selecting the respective groups of loss event records from the plurality of loss event records based on the respective loss event type of each loss event record included in the respective groups of loss event records.

6. The method of claim **1**, wherein the data disclosure type corresponds to at least one of:

a data breach;

a data theft;

a data loss; and

an unintentional data disclosure.

7. The method of claim **1**, wherein the business interruption type corresponds to at least one of:

a cyber extortion event;

a network disruption; and

a website disruption.

8. The method of claim **1**, wherein the fraud type corresponds to at least one of:

an identity fraud event;

a phishing event; and

a skimming event.

9. The method of claim **1**, wherein the executing, for each group of loss event records, the plurality of Monte Carlo simulations to generate the respective loss simulation data further comprises:

determining a statistic from the respective loss values of the loss event records included in the group;

weighting the statistic based on the results for the cyber security assessment of the entity to determine a weighted statistic; and

executing the plurality of Monte Carlo simulations based on the weighted statistic.

10. The method of claim **1**, wherein the cyber security assessment comprises an outside-in cyber security assessment or an inside-out cyber security assessment.

11. The method of claim **1**, wherein the materiality loss value is based on an industry indicator corresponding to the entity and a revenue corresponding to the entity, and further comprising:

determining a respective materiality ratio for each respective loss simulation data, wherein the each of the respective materiality ratios are based on the materiality loss value corresponding to the entity; and

selecting the respective loss simulation data corresponding to a largest materiality ratio of the materiality ratios.

12. The method of claim **11**, wherein the identifying the expected probability value corresponding to the materiality loss value of the entity further comprises:

generating a loss exceedance curve indicative of a probability of loss potential for the entity based on the selected loss simulation data; and

identifying, from the loss exceedance curve, the expected probability value corresponding to the materiality loss value of the entity.

13. The method of claim **1**, further comprising:

obtaining signal data indicative of a cyber resilience of the entity;

generating, based on a first subset of the signal data, the fortitude factor score, wherein the first subset of the signal data is indicative of the cyber security control posture of the entity; and

generating, based on a second subset of the signal data, the governance factor score, wherein the second subset of the signal data is indicative of the administration of cyber security controls by the entity.

14. A system for providing a cyber resilience rating for an entity of a plurality of entities, the system comprising:

one or more computing systems programmed to perform operations comprising:

obtaining a plurality of entity indicators corresponding to the plurality of entities, wherein each of the plurality of entity indicators comprises characteristic information for a respective entity of the plurality of entities, and wherein each of the plurality of entities corresponds to a respective entity indicator of the plurality of entity indicators;

determining a peer group for the entity based on the respective characteristic information for the entity, wherein the peer group comprises a subset of the plurality of entities;

obtaining a plurality of loss event records for the peer group, wherein each loss event record comprises a respective loss value and corresponds to a cyber event associated with a respective entity of the peer group, wherein respective groups of loss event records selected from the plurality of loss event records correspond to a data disclosure type, a business interruption type, and a fraud type;

executing, for each group of loss event records, a plurality of Monte Carlo simulations to generate respective loss simulation data based on the respective loss values of the loss event records included in the group and results for a cyber security assessment of the entity;

identifying, based on the respective loss simulation data for each group of loss event records, an expected probability value corresponding to a materiality loss value of the entity;

providing a risk factor score indicative of a cyber security risk of the entity based on the identified expected probability value; and

providing a cyber resilience rating for the entity based on a combination of the risk factor score, a fortitude factor score, and a governance factor score, wherein the fortitude factor score is indicative of a cyber security control posture of the entity, and wherein the governance factor score is indicative of an administration of cyber security controls by the entity.

15. The system of claim **14**, wherein the characteristic information comprises an industry indicator, a geography indicator, and a size indicator for the respective entity.

16. The system of claim **15**, wherein the determining the peer group for the entity based on the respective entity characteristics of the entity further comprises:

selecting, from the plurality of entities, the subset of the plurality of entities for inclusion in the peer group based on the respective characteristic information corresponding to each entity of the subset of the plurality of entities comprising at least one of: the industry indicator, the geography indicator, and the size indicator corresponding to the entity.

17. The system of claim **14**, wherein the peer group comprises a first peer group and a second peer group, wherein the first peer group and the second peer group comprise different subsets of the plurality of entities.

18. The system of claim **14**, wherein each loss event record of the plurality of loss event records comprises a respective loss event type corresponding to one of: the data disclosure type, the business interruption type, or the fraud type, and wherein the operations further comprise:

selecting the respective groups of loss event records from the plurality of loss event records based on the respective loss event type of each loss event record included in the respective groups of loss event records.

19. The system of claim **14**, wherein the data disclosure type corresponds to at least one of:

a data breach;

a data theft;

a data loss; and

an unintentional data disclosure.

20. The system of claim **14**, wherein the business interruption type corresponds to at least one of:

a cyber extortion event;

a network disruption; and

a website disruption.

* * * * *