Risk Assessment and Mitigation Phase (RAMP) Workshop

PG&E

12/15/17

Agenda

- Introduction (45 min)
- Model Overview (45 min)
- Safety Culture (15 min)

- Lunch

- Transmission Pipe Rupture with Ignition (30 min)
- Release of Gas with Ignition on Distribution Facilities – Non-Cross Bore (30 min)
- Wildfire (30 min)
- Contractor Safety (30 min)
- Cyber Attack (30 min)

Risk Assessment and Mitigation Phase (RAMP) Introduction (Chapter A)

Janaize Markland, Enterprise and Operational Risk Management and Insurance

12/15/17

Risk Management at PG&E

2011-2012

- Establish additional governance and oversight
  - Risk and Compliance Committees
  - Policies and Procedures

2013

- Establish Line of Business risk registers
- Establish company risk register
- Risk Evaluation Tool (RET) Version 1

2014

- Further refine company risk register
- Use risk evaluation tool to compare risks across the company
  - Risk Evaluation Tool (RET) Version 2
  - Beginning quantification efforts (metrics)

2015

- Continue quantification efforts through data inputs into the RET v2

2016

- Continue quantification efforts as well as begin risk tolerance discussion

2017

- RAMP: 22 first generation probabilistic models
- Helped us apply quantification to risk decisions

2018

- Continue refining models
  - Skillset enhancements
  - Data collection plans
  - Transparency in decision making
  - Alignment of risk to spend

2019

- Adoption of S-MAP decision
- Continue building out additional models

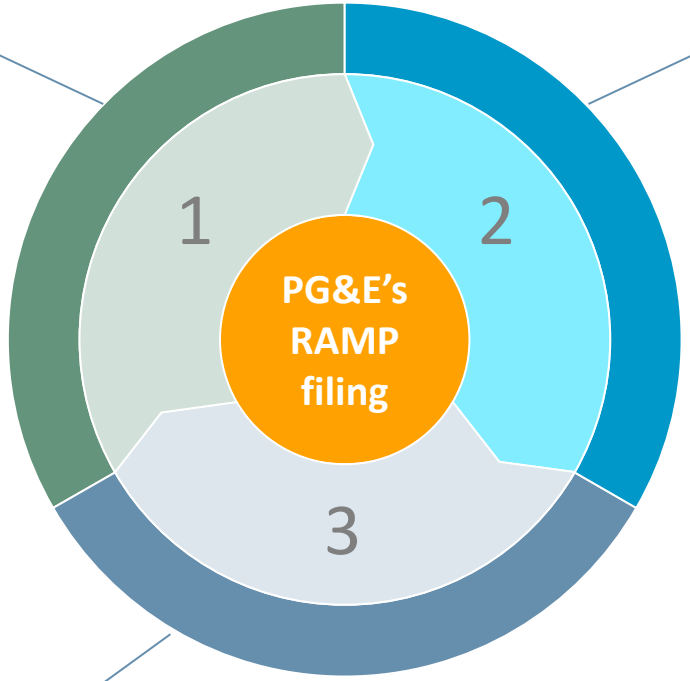
2020

- File 2nd RAMP
- Data driven decision making, based on probabilistic models

Approach to PG&E's RAMP Filing

1. Transparency

- Industry data is publically available; PG&E data is available upon request
- Models are documented (both in-model and a user guide)
- Risk calculations are transparent in Excel
- Probabilistic approach outlines the full distribution of outcomes



2. Accountability

- Mitigation programs are connected with measurable risk driver frequencies and/or consequences
- Risk reduction estimates are quantified (e.g. reduction in injuries per year) and can be tracked
- Quantification of both risk reduction and spend allows measurement of progress

3. Participatory inclusivity

- Approach has been shared with the Joint Intervenors and modified to suit objectives of multiple parties
- Common risk dimensions (safety, reliability, etc.) have been shared with other utilities and the CPUC

Choosing the Risks for RAMP

- Began with the Session D 2017 top risk list (based on the Risk Evaluation Tool (RET) score)
- Applied a criteria that anything in the Top Risk List at Session D 2017 that scored a 4 or above in Safety would be included in the RAMP filing
    - 4 or Above in Safety Criteria: Permanent/Serious Injuries or Illnesses – Few serious injuries or illnesses to the public or employees

Chp	Name	LOB
1	Transmission Pipeline Failure – Rupture with Ignition	Gas Operations
2	Failure to Maintain Capacity for System Demands	Gas Operations
3	Measurement and Control Failure – Release of Gas with Ignition Downstream	Gas Operations
4	Measurement and Control Failure – Release of Gas with Ignition at M&C Facility	Gas Operations
5	Release of Gas with Ignition on Distribution Facilities – Cross Bore	Gas Operations
6	Compression and Processing Failure – Release of Gas with Ignition at Manned Processing Facility	Gas Operations
7	Release of Gas with Ignition on Distribution Facilities – Non-Cross Bore	Gas Operations
8	Natural Gas Storage Well Failure – Loss of Containment with Ignition at Storage Facility	Gas Operations
9	Distribution Overhead Conductor – Primary	Electric Operations
10	Transmission Overhead Conductor	Electric Operations
11	Wildfire	Electric Operations
12	Nuclear Operations and Safety – Core Damaging Event	Generation
13	Hydro System Safety – Dams	Generation
14	Contractor Safety	Safety and Health
15	Employee Safety	Safety and Health
16	Motor Vehicle Safety	Safety and Health
17	Lack of Fitness for Duty Awareness	Safety and Health
18	Cyber Attack	Information Technology
19	Insider Threat	Information Technology
20	Records and Information Management	Enterprise Records and Information Management
21	Skilled and Qualified Workforce	Human Resources
22	Climate Resilience	Strategy and Policy

RAMP Requirements

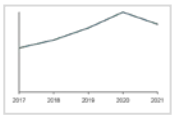
#	Requirements (D.16-08-018)	How We've Addressed the Requirement
1	Identify Top Risks	• PG&E used the 2017 Session D Top Risk list to identify the top safety risks for the company that have been included in the RAMP
2	Describe the controls or mitigations currently in place	• In Sections III and IV of the risk chapters, generally there is an explanation of current controls and current mitigations
3	Present its plan for improving the mitigation of each risk	• In Sections V of the risk chapters, generally there is an explanation of future/proposed mitigations
4	Present two alternative mitigation plans that it considered	• In Section VI of the risk chapters, generally there is an explanation of two alternate mitigation plans considered
5	Present an early stage "risk mitigated to cost ratio" or related "risk reduction per dollar spent"	• In Sections V and VI of every chapter, the RSE by mitigation and by plan is presented
6	Identify lessons learned in the current round to apply in future rounds	• In the Executive Summary and Section VIII of generally every chapter there is a discussion of lessons learned and next steps
7	Move toward probabilistic calculations as much as possible	• Each RAMP risk has a probabilistic model
8	For those business areas with less data, improve the collection of data and provide a timeframe for improvement	• Each chapter discusses lessons learned and next steps
9	Describe the company's safety culture, executive engagement, and compensation policies	• There is a Safety Culture Chapter (Chapter C) that covers culture and executive engagement; Chapter D covers compensation policies
10	Respond to immediate or short-term crises outside of the RAMP and GRC process	• The process for responding to immediate or short-term crises outside the RAMP and GRC process is covered on page A-2
11	Remove shareholders' financial interest from consideration in risk models and decision frameworks used to support rate case expenditure proposals	• Below the line costs are excluded from our RAMP filing and models
12	Explicitly include calculation of risk reduction and a ranking of mitigations based on risk reduction per dollar spent	• A ranking of mitigations by RSE can be found in work paper B-60
13	PG&E's November 2017 RAMP filing shall include GT&S	• GT&S risks are included in the RAMP filing (chapters 1, 2, 3, 4, 6, 8)
14[1]	PG&E should strive for reasonable rates of steady state replacement, consistent with risk-informed decision making, for crucial operating equipment necessary to provide safe and reliable service	• Covered in Appendix 2 of the Report
15[1]	For the Reliability Program investments in the Electric LOB, PG&E should strive to install equipment necessary or useful to providing reliable service consistent with a holistic and measured approach to system reliability solutions.	• Covered in Appendix 2 of the Report

[1] Decision 17-05-013

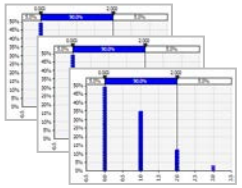
Modeling Methodology-Bow Tie

A bow tie approach encapsulates drivers and consequences of a risk event and, with probabilistic simulation tools, can be used to quantify overall risk

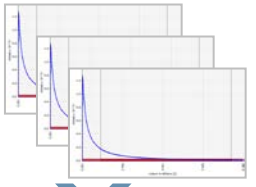
Input: *Forecast exposure through time*



Input: *Historical data and SME information*



Input: *Historical data and SME information for a single risk event*



Drivers

Exposure

Miles of pipeline

Hours worked

Number of employees

Frequency

Driver #1 Frequency [events / mile / year]

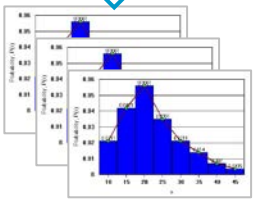
Driver #2 Frequency [events / hour / year]

Driver #3 Frequency [events / person / year]

Risk event(s)

Consequences

- Safety (Injuries/fatalities)
- Reliability
- Trust
- Environmental
- Compliance
- Financial



Output: *Monte Carlo simulation result for all consequence dimensions and all risk events*

Risk = *f* (Exposure, Frequency, Consequences**)**

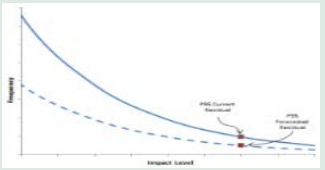
RAMP Filing Assumptions

1. This is PG&E's first RAMP filing; we will learn as we go

- Current level of quantification will make repeatability and validation challenging.

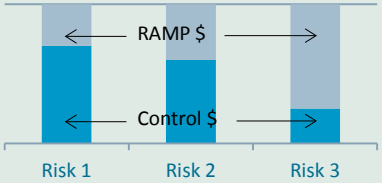
2. Every RAMP risk will have a top down model based on available data

- Model inputs based on PG&E data, industry data, and calibrated SME judgement



3. Risk Spend Efficiency will not be calculated for baseline control costs but will be provided for mitigations in the GRC time period

- RSE calculations will not be made for current controls.

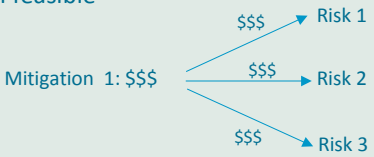


4. Risk Spend Efficiency will be summed over '17 to '22 time period divided by cost

- The structure of the model allows for costs and risk reduction estimates to be inputted yearly; however, for the RAMP filing, these inputs will be high level, first generation estimates.
- Mitigations and reduction benefits will be limited to what is achievable during the GRC cycle

5. Costs for mitigations that impact multiple risks counted multiple times will be allocated when feasible

- Given current state of risk quantification, allocation of mitigations to specific risks is imprecise
- Best efforts will be made to allocate costs and estimate benefits across multiple risks, when feasible



6. There will be increased justification for choosing to implement a low RSE mitigation over a higher RSE mitigation

- Some activities with low (or no) RSE may still be foundational to other mitigations or the data modeling . Some mitigations with high RSE may not be executable.
- Additional risk reduction beyond the general rate case horizon will be further supplemented in the RAMP testimony

Mitigation	RSE
A	###
B	###
C	###

RAMP Filing Assumptions

7. Below the Line (BTL) costs, as defined by PG&E's BTL Standard, will be excluded from the RAMP filing

- Removing BTL dollars addresses RAMP requirement to exclude shareholder related costs

✓ *Above the line costs*

Below the line costs

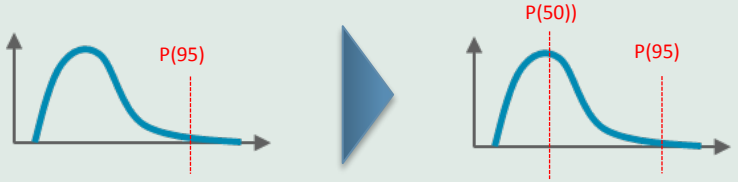
8. We will be using a consistent approach for PCC related costs

- For mitigations that are inclusive of PCC costs, we will estimate the number of associated FTE hours and multiply that by the standard employee rate for the specific job function

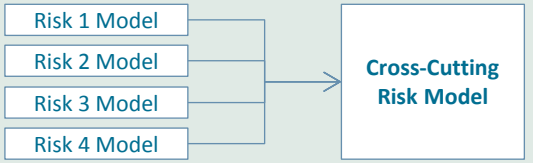
FTE Hrs x Standard Rate

9. For RAMP, PG&E will consider impacts to tail and expected value

- PG&E will use tail average and expected values when considering risk mitigations.



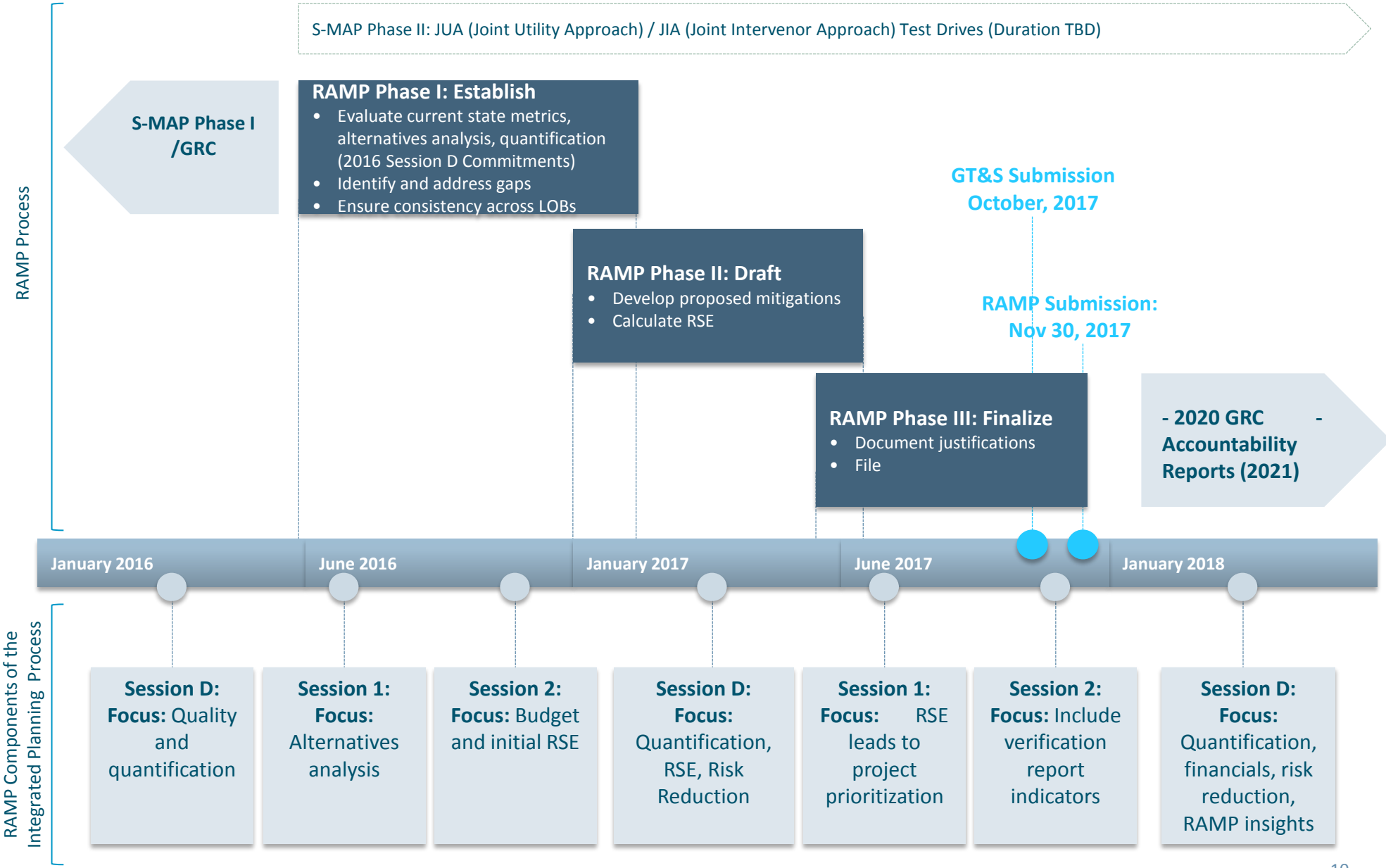
10. Cross-cutting risk models are based on outputs from other RAMP models



11. Given the varying level of data maturity across risks, some risks will be given a modified RAMP treatment

RAMP Treatment	Modified RAMP Treatment
Full, probabilistic, quantitative model developed and submitted as part of the filing	
Significant industry and/or PG&E data maturity	Less mature data (e.g. less comprehensive data, few historical events)
Written testimony combined with risk spend efficiency calculations will be used to support mitigation choices	Will rely primarily on written testimony to support mitigation choices

RAMP Timeline and Approach



Key Learnings During the Process:

- **Quantitative Operational Risk Modeling**
  - We see the value in the potential of probabilistic operational risk modeling, not only for deepening understanding of risks but for enabling data-driven, risk-informed decision making.
  - This quantitative approach can also support to transparent discussions about risk, mitigation strategies, and levels of risk.
  - This transition will involve the development of new skills, techniques, and data sources

- **Governance, Oversight, and Evolution**
  - In order to better understand longer term risk reduction potential beyond the 6-year time horizon, we will need to refine operational risk models to accommodate this type of analysis
  - We have started creating a governance structure for the management and development of these risk models

- **Risk Tolerance**
  - The modeling effort has provided greater transparency in decision making, which will allow the company to discuss current levels of risk and contemplate new mitigations

- **Interrelationships between risks**
  - As we continue to refine our approach to risk modeling, improvements will be made in identifying and understanding how risks interrelate

- **Tracking of Associated Financials**
  - We have made adjustments in SAP to incorporate RAMP related IDs to track mitigation costs for future accountability reporting

- **Data Availability**
  - The completeness and availability of relevant data remains a challenge we will continue to address as we refine our approach to modelling

Risk Model Overview
(RAMP Chapter B)

Jamie Lubeck, Enterprise and Operational Risk Management

12/15/17

The objective of this section is to explain the methodology employed in developing the 22 first generation models used to probabilistically assess the consequence of various risks reported in PG&E's 2017 RAMP filing.

In the development of these models the following objectives were achieved:

- "[M]ov[ing] toward probabilistic calculations as much as possible";
- Developing a consistent approach for quantitative modeling for different types of risk;
- Comparing risks across Lines of Business (LOB);
- Presenting an early stage "'risk mitigated to cost ratio' or related 'risk reduction per dollar spent'" – using quantitative risk assessment methods;
- Outlining all assumptions and inputs used in each model – using a consistent approach and record of the analyses and assumptions; and
- Modeling risks through the GRC period – emphasizing quantitative analytics as compared to subjective judgement when addressing risk drivers.

@Risk is an Excel add-in that Enables Execution of Probabilistic/Monte Carlo simulations

Simulation creation, execution, and interpretation is simple and streamlined

@RISK (pronounced “at risk”) performs risk analysis using Monte Carlo simulation to show you many possible outcomes in your spreadsheet model— and tells you how likely they are to occur. It mathematically and objectively computes and tracks many different possible future scenarios, then tells you the probabilities and risks associated with each different one.(http://www.palisade.com/risk/) .

During a Monte Carlo simulation, values are sampled at random from the input probability distributions. Each set of samples is called an iteration, and the resulting outcome from that sample is recorded. Monte Carlo simulation does this hundreds or thousands of times, and the result is a probability distribution of possible outcomes (http://www.palisade.com/risk/monte_carlo_simulation.asp).

Why we’re using it

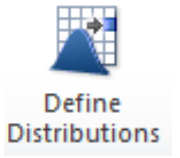
- **RAMP filing** emphasis on probabilistic approach requires additional modeling tools
- **Professional software** has a proven track-record and is widely used
    - @Risk by Palisade was developed in 1987
- **Improve and standardize** PG&E’s approach to evaluating risks
    - @Risk is used in other parts of PG&E

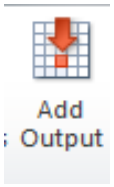
What it is

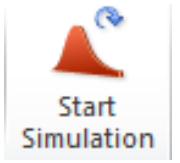
- Requires a purchased license to run
- @Risk is an **Excel add-in** (.xla file) that adds a ribbon to allow Monte Carlo simulation

How it works

- **Three main operations:**
    1. Define input probability distributions
        - Look at the raw data
        - Subject matter expertise
    2. Define output probability distributions
        - Using standard Excel, use formulas that combine input distributions
    3. Run simulations
        - Set the number of iterations
        - Run the simulation
        - Interpret the results
        - Save the results in-file or externally







A bow tie approach encapsulates drivers and consequences of a risk event and, with probabilistic simulation tools, can be used to quantify overall risk

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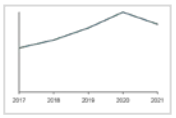

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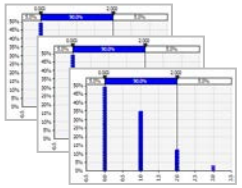

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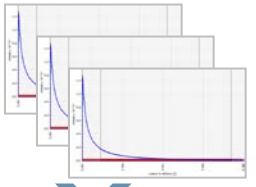


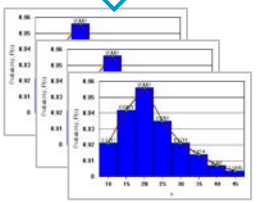
Drivers

Consequences

Exposure	Frequency
Miles of pipeline	Driver #1 Frequency [events / mile / year]
Hours worked	Driver #2 Frequency [events / hour / year]
Number of employees	Driver #3 Frequency [events / person / year]

Risk event(s)

- Safety (Injuries/fatalities)
- Reliability
- Trust
- Environmental
- Compliance
- Financial



Output: *Monte Carlo simulation result for all consequence dimensions and all risk events*

Risk = *f* (Exposure, Frequency, Consequences**)**

Baseline Modeling:

A Risk Event

- Center of the bow tie
- What event do we need to monitor?

B Exposure

- Define exposure granularity of risk event
- What is the asset or non-asset measure that fundamentally affects the risk?

C Drivers and Frequency

- Define drivers and input distributions of the drivers on a frequency per exposure
- What is the frequency of event drivers per exposure per time?

D Consequences

- Define input distributions of the consequences for defined risk event
- If an event happens, what are the range of consequences?

E Run Simulation

- Select number of iterations

F Output

- Review output distributions

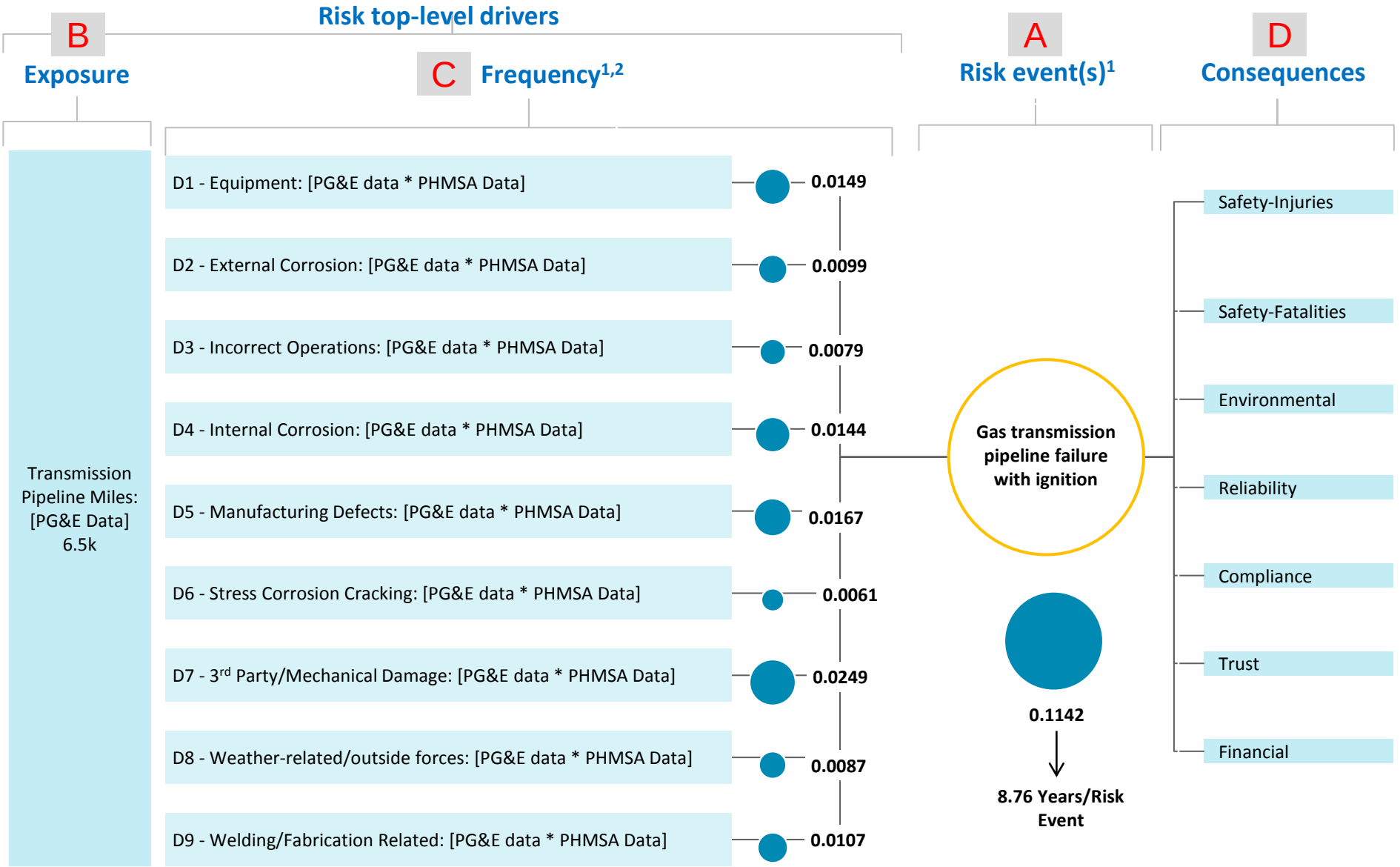
G Tail Average

- Extract the tail average values from output distributions (average of the 90-100%)

H Multi-Attribute Risk Score (MARS)

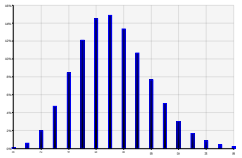
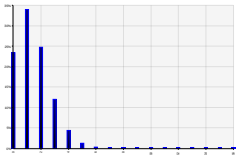
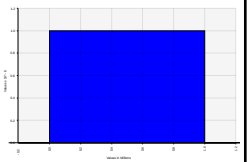
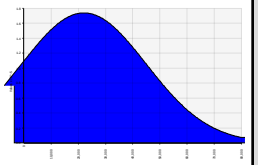
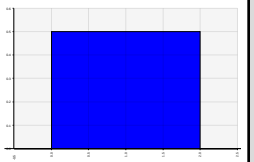
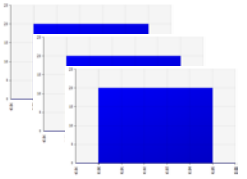
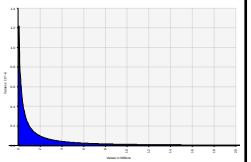
- Calculate the baseline MARS score using consistent ranges and weights throughout all risks

01 – GAS – Gas Transmission Pipeline Failure with Ignition – Year 1



[1]Values displayed are means of each distribution and are in the units of events/year. Driver frequencies are summed to obtain the Risk event frequency.
[2]Drivers are modeled using Poisson and Binomial distributions.

01 – GAS – Gas Transmission Pipeline Failure with Ignition – Consequences

D	Safety-Injuries	Safety-Fatalities	Environmental	Reliability	Compliance	Trust	Financial
Source	PHMSA	PHMSA	PG&E Data	PG&E Data	NA	PG&E Data	PHMSA
Consequence Distributions	Percent of onshore, ignited incidents with injury or fatality=13.3% Mean=7.2 (Poisson) 	Percent of onshore, ignited incidents with injury or fatality=13.3% Mean=1.5 (Poisson) 	Min=$0 Max=$1M (Uniform) 	System likelihood of customer outage =12% x Customers (Normal): Ave=22k Std Dev=23k  x Customer minutes (Uniform): Min=0 days *24*60 Max=2 days *24*60 		Dependent on Safety outcomes. If there are any fatalities= High severity brand favorability change If there are injuries without fatalities, 50/50 chance of Low or Severe High severity=12-20% Severe=5-12% Low=0-5% (Uniform) 	Ave=$8.6M Std Dev=$61.2M (Lognormal) 

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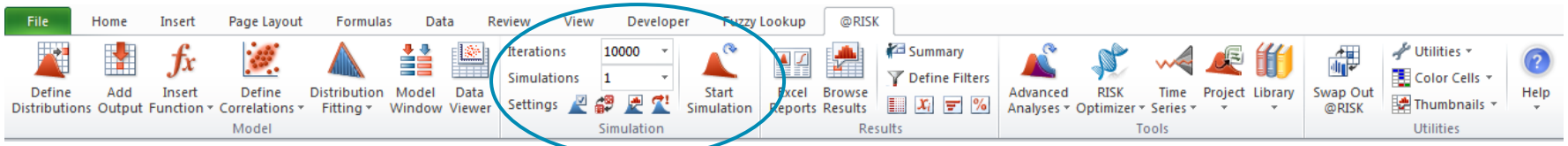
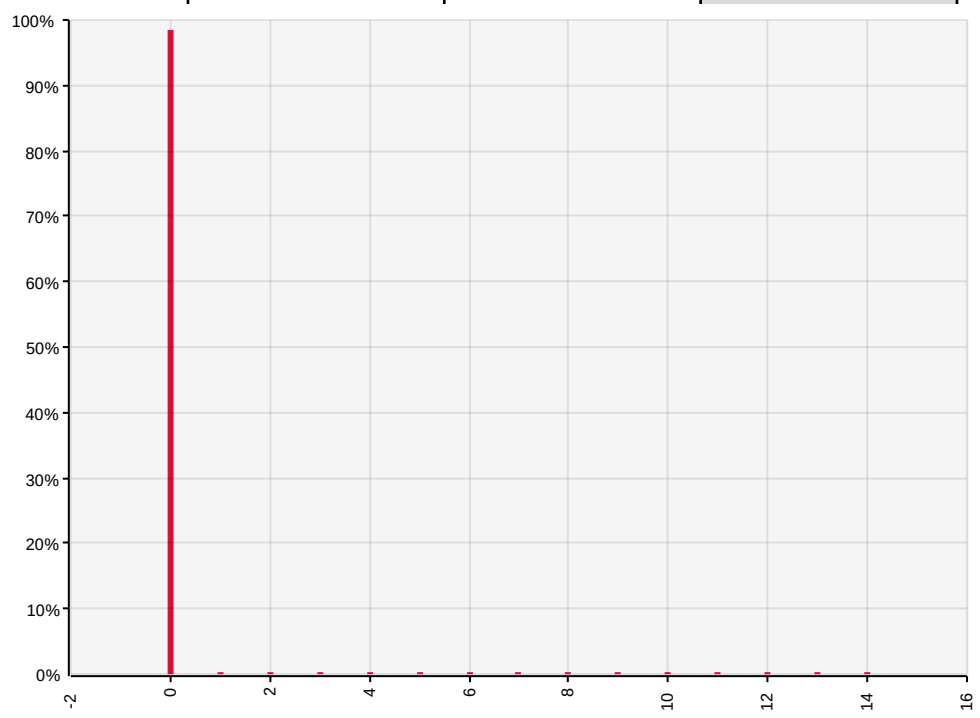


01 – GAS – Gas Transmission Pipeline Failure with Ignition – Outcomes

F	Safety-Injuries	Safety-Fatalities	Environmental	Reliability	Compliance	Trust	Financial
	Year 1	Year 1	Year 1	Year 1	NA	Year 1	Year 1
Outcome Distributions	Mean:0.10 P50:0 P95:0 P99:6 Max:14	Mean:0.02 P50 P95 P99 Max	Mean:59,036	Mean: 739,955		Mean: 0.2% P50: 0% P95:0% P99:14% Max:20%	Mean: 1,001,246 P50: 0 P95: 1,760,810 P99: 18,595,589 Max: 611,750,014



G	Year 1-6					Year 1-6	Year 1-6
Outcome -EV-NU[1]	0.11					0.2%	$ 968,839
Outcome -TA-NU[2]	1.06	0.22	$ 565,851	6,299,387		2.0%	$ 9,685,119

[1]Ave of Year 1-6 Expected Value outcomes in Natural units (added for presentation purposes, not shown in Risk Chapters)
[2]Ave of Year 1-6 Tail Ave outcomes in Natural units

Consequence dimensions can be condensed into a single risk score by choosing ranges and weights

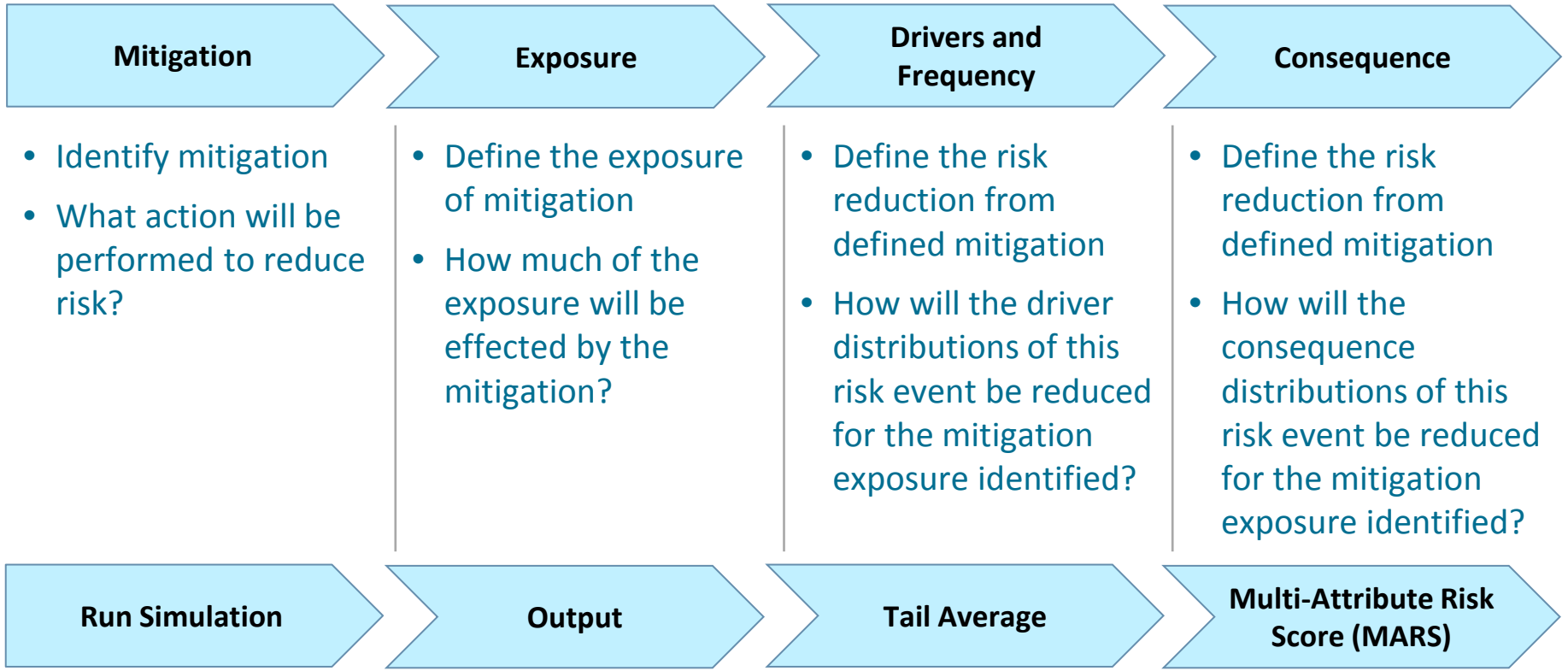
H

Baseline

Consequence dimension	Place holder Range	Placeholder Weight	01-GAS TA	Compute Risk Scores per attribute: $\frac{Outcome\ measurement}{Range} x\ Weight\ x\ Scaler^1$ 01-GAS Risk Score
Injuries / year	0 to 1,000	3%	1.06	$\frac{1.06}{1,000} x\ 3\%\ x\ 10{,}000 = 0.29$
Fatalities / year	0 to 100	27%	0.22	$\frac{0.22}{100} x\ 27\%\ x\ 10{,}000 = 5.94$
Environmental / year	0 to 5,000,000,000	5%	$565,851	$\frac{565{,}851}{5{,}000{,}000{,}000} x\ 5\% x\ 10{,}000 = 0.06$
Reliability / year	0 to 1,000,000,000	25%	6,299,387	$\frac{6{,}299{,}387}{1{,}000{,}000{,}000} x\ 25\% x\ 10{,}000 = 15.75$
Compliance / year	0 to 5,000,000,000	5%	-	$\frac{0}{5{,}000{,}000{,}000} x\ 5\% x\ 10{,}000 = 0.00$
Trust / year	0 to 100%	5%	2.0%	$\frac{2.0}{100} x\ 5\% x\ 10{,}000 = 9.78$
Financial / year	0 to 5,000,000,000	30%	$9,685,119	$\frac{9{,}685{,}119}{5{,}000{,}000{,}000} x\ 30\% x\ 10{,}000 = 5.81$
			MARS	(Sum of all attribute values) 37.62

[1]Scaler chosen from 0-10,000 in line with RET scaling

Mitigation Modeling: Begin with Baseline model



Illustrative

Modeling Methodology-Mitigation

Exposure

…what is the asset or non-asset measure that fundamentally affects the risk?

Miles of transmission pipeline

Example data:
10,000 total miles

Frequency

…what is the frequency of event drivers per exposure per time?

λ

 # major incidents / mile / year

Example data:
42 external corrosion major incidents /
7 years / all US pipeline miles

Consequence

…if an event happens, what are the consequences?

Safety, Reliability, Financial, etc.

Example data:
Average 10 injuries / ignition event
Average 1 fatality / ignition event

Mitigations

…which programs alter the frequency or consequences of risk events? By how much? To what exposure are they applied?

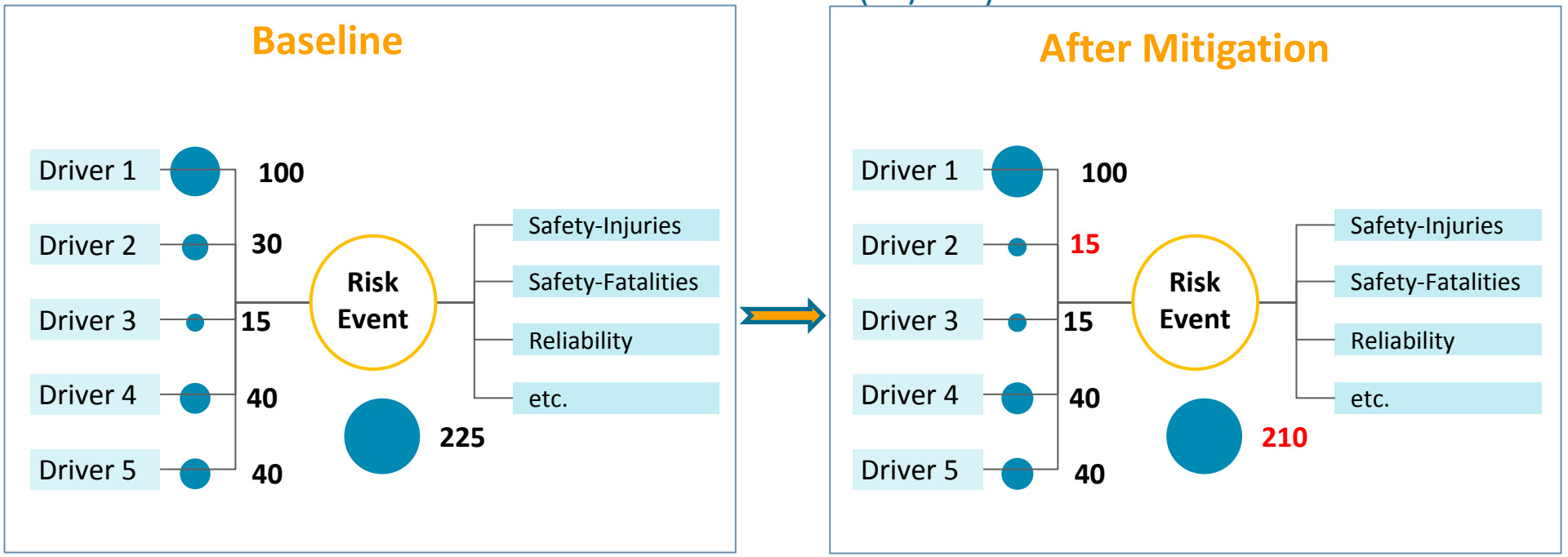
100 miles **90% reduction to driver 1** **0% reduction**

Example: This mitigation reduces frequency of manufacturing defects **by 90%** but has no effect on consequences

Illustrative- Baseline vs Mitigation Bow Tie

Example Mitigation:

Driver 2 mean frequency is reduced by 50% = (15/30) → Resulting in an overall frequency reduction of 7% = (15/225)



Risk Spend Efficiency

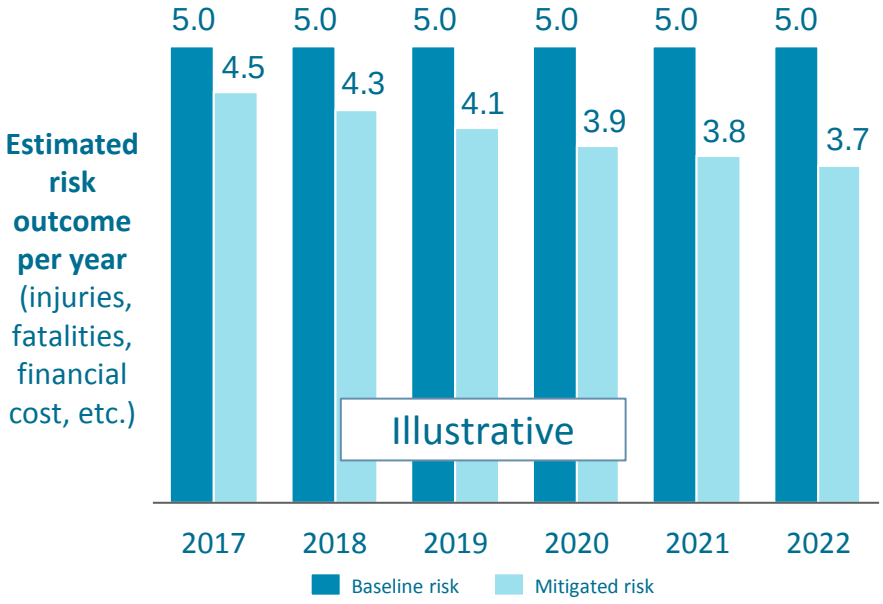
$$RSE_{MARS} = \frac{MARS_{baseline} - MARS_{mitigated}}{\$}$$

Baseline and Mitigated Risk Outcomes for Consequences

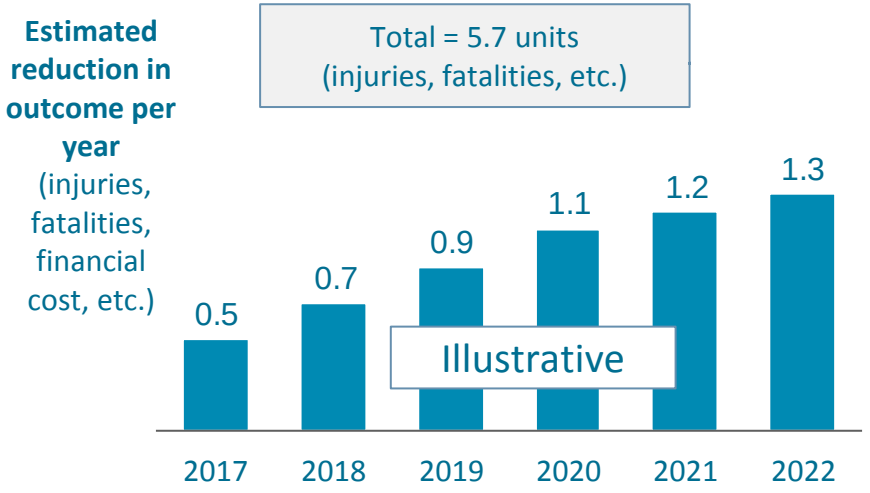
Example output: Baseline and mitigated risk outcomes for consequences

Understanding the basic risk calculation methodology allows measurement of risk reduction (baseline vs. mitigated) and calculation of an RSE

Illustrative risk outcome for a consequence dimension v. time



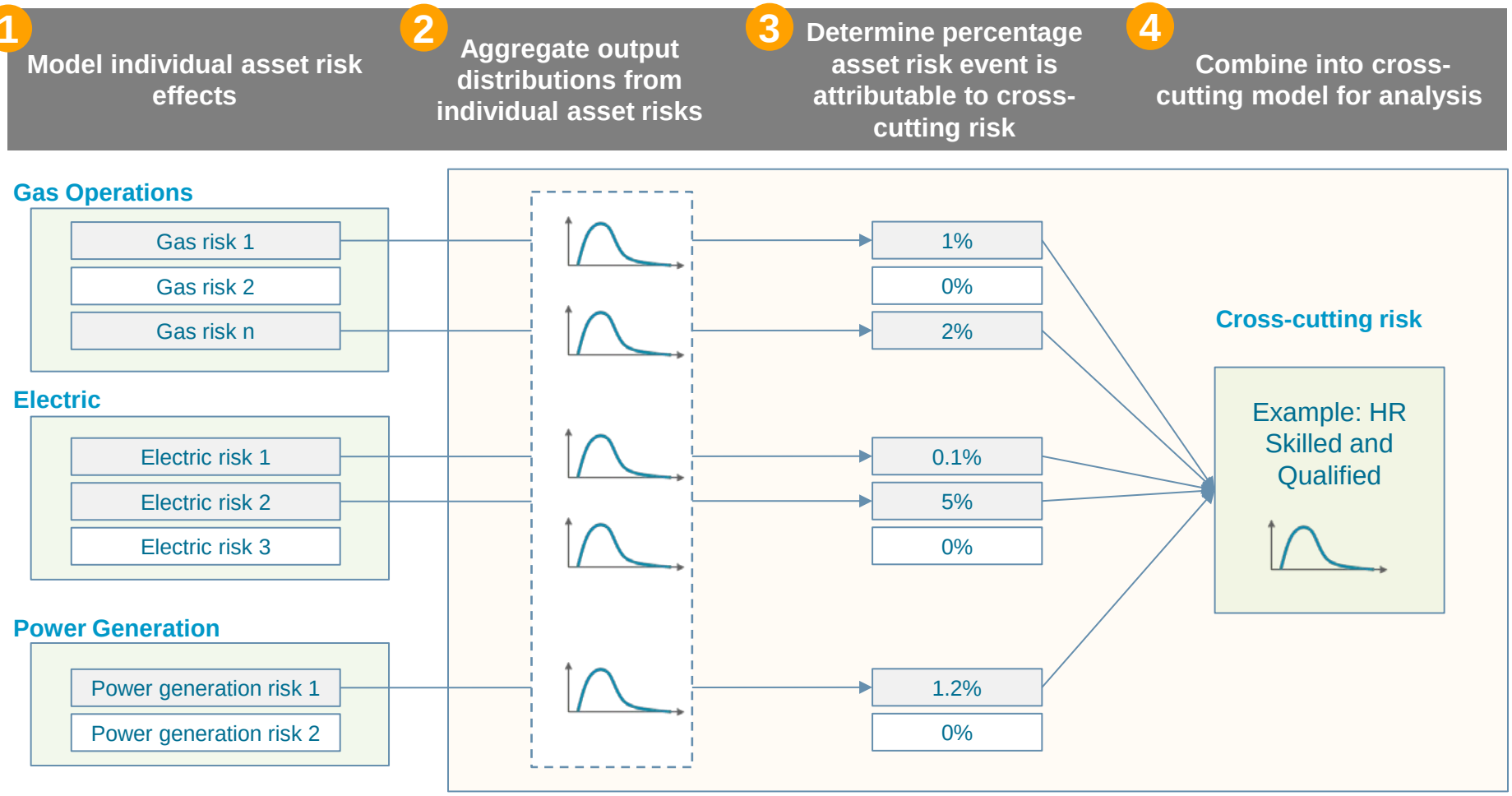
Risk reduction v. time (example for single mitigation program)



$$RSE = \frac{\sum Risk\ reduction}{\sum Cost} = \frac{5.7}{\$100} = 0.057$$

Risk common currency (injuries, fatalities, etc.) per USD

Cross-cutting risk effects must be aggregated across individual asset models



Model assumptions and potential future refinements

Model subset	Assumptions/Next Steps
Risk Event	• Enhanced clarity on **stand-alone** and **cross-cutting** risks around the risk scope • Enhanced clarity on impacting **drivers** and resulting **consequences** to a risk event • Continue to refine the definition of risk events
Exposure	• **High-level model:** Exposures have not been differentiated by asset attributes (e.g. diameter of pipe, vintage / age of asset, type of conductor, location, etc.) – all exposures are assumed to have the same risk profile • For RAMP these models help to determine ***what*** to do NOT ***where*** to do it*
Frequency drivers	• Frequency estimates leverage **industry** data, **PG&E** data, or **SME** input (as needed and available to robustly quantify the risk) • Frequency probability **distributions** are sampled • Varying levels of data availability among the risks
Consequences	• Consequence estimates (range of possible outcomes) leverage **industry** data, **PG&E** data, and **SME** input (as needed and available) • Consequence probability **distributions** are sampled after risk events • More education and calibration across risks • Refinement of attributes to be determined from S-MAP decisions
Mitigations	• Mitigations apply to an **exposure** (% of total exposure) and can either reduce **frequency** drivers, **consequence** distributions, or **both** • **Mitigation effectiveness** estimates are informed by data and **SME input**

Establish governance process to maintain and progress risk modeling for the future
Continuing education on risk based decision making

*Models that determine **where** to do the work are used for shorter term project level resource dispatching

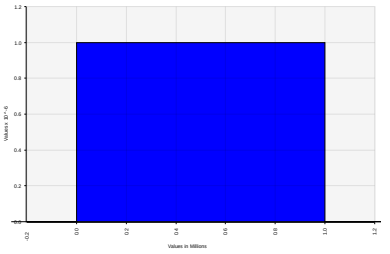
Questions

A fundamental objective of RAMP is to move to probabilistic calculations and away from individual scenario based scoring to a range of possible outcomes. This is facilitated by using statistical distributions to model potential inputs. Depending on the nature of the risk driver and the type of data available, PG&E relied on a variety of distributions to describe the ranges and subject matter based judgements were made on which distributions to use for each model input. The selection of which distribution to use is not a science and outcomes can change with any adjustment to input distributions.

There are two main types of distributions: discrete and continuous. Discrete distributions take on distinct or separate values while continuous distributions can take on any value.

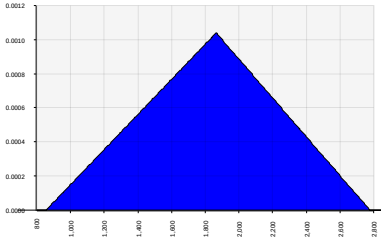
- Uniform (continuous distribution)

The RiskUniform function creates a simple distribution where all continuous values between a minimum and maximum are equally possible. This is typically used when there is only information on a minimum and maximum value and nothing else is known about the uncertain event (random variable). A uniform distribution with a maximum of 10,000 and minimum of 0 has equal probability for all random samples between the 10,000 and 0.



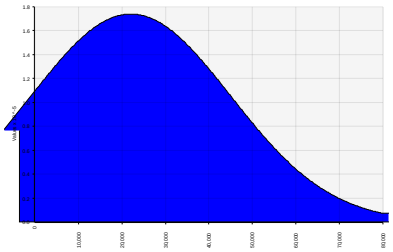
- Triangular (continuous distribution)

The RiskTriang function creates a simple and versatile function for modeling a continuous distribution when we only have data for the minimum, maximum, and most likely (mode) values of the uncertain event (random variable). The probability density function of such distribution has a triangle shape: increasing from the minimum value to a peak at the most likely value and then decreasing to the maximum value.



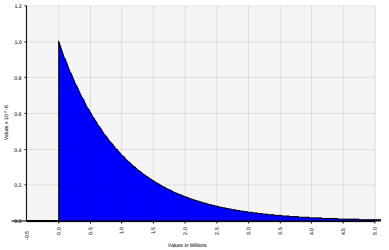
- Normal (continuous distribution)

The RiskNormal function creates the symmetrical bell-shaped distribution which is defined by the average or mean and standard deviation. The standard deviation indicates the spread of the distribution where a smaller standard deviation indicates a narrower bell-shaped curve. Many large set of losses roughly follows a normal distribution such as the number of customers affected during an outage. The minimum and maximum values of a normal distribution are negative infinity and positive infinity, respectively. However, these distributions can be truncated if, for example, only non-negative values are reasonable outcomes.



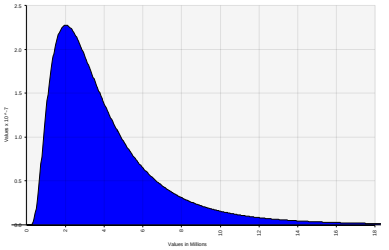
- Exponential Decay (continuous distribution)

The RiskExpon function creates a continuous non-negative distribution, of which the probability density function decreases at a rate proportional to its current value. This distribution has a single scale parameter, its mean. The density function of such distributions always decreases from a modal value at 0. That is, the most likely values are always small values. This function is typically used when a loss happens significantly more often around zero, has fewer mid-range losses, and has a tail of significantly larger losses. If the mean is known, then the RiskExpon function can be used.



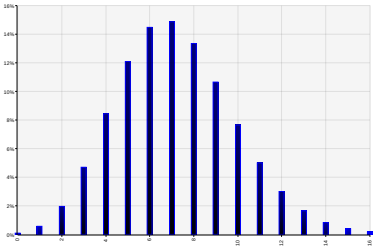
- Log normal (continuous distribution)

Similar to the normal distribution, the RiskLognorm function creates a distribution with a given mean and standard deviation. However, unlike the normal distribution the log normal distribution has only positive values. This characteristic is similar to an exponential decaying distribution, however, the log normal distribution does not have a modal value of 0 but has a modal value of non-negative value.



- Poisson (discrete distribution)

The RiskPoisson function generates a distribution with non-negative integer values. This distribution is often used to describe the number of "events" in some amount of time such as the number of equipment failures in a year. It has a single parameter, usually denoted by the Greek λ (lambda), which is the mean and variance of the distribution. This parameter can be interpreted as a rate.



If the equipment failures of a risk event is λ =125 failures events per year, on average, the RiskPoisson function can be used to create a discrete distribution with mean 125. It is important to note that a discrete distribution should be used when a failure is binary (i.e., a failure occurs or it does not occur).

- Binomial and Bernoulli (discrete distributions)

The RiskBinomial function is used to create a distribution of the number of "successes" in a sequence of n independent trials when the probability of success, p, remains constant from trial to trial.

A situation where you would use this function is to model the outcomes of flipping 10 fair coins where heads is a "success". There are 10 flips or 10 independent trials (n=10), with a probability, p, of obtaining a successful head outcome 50 percent of the time.

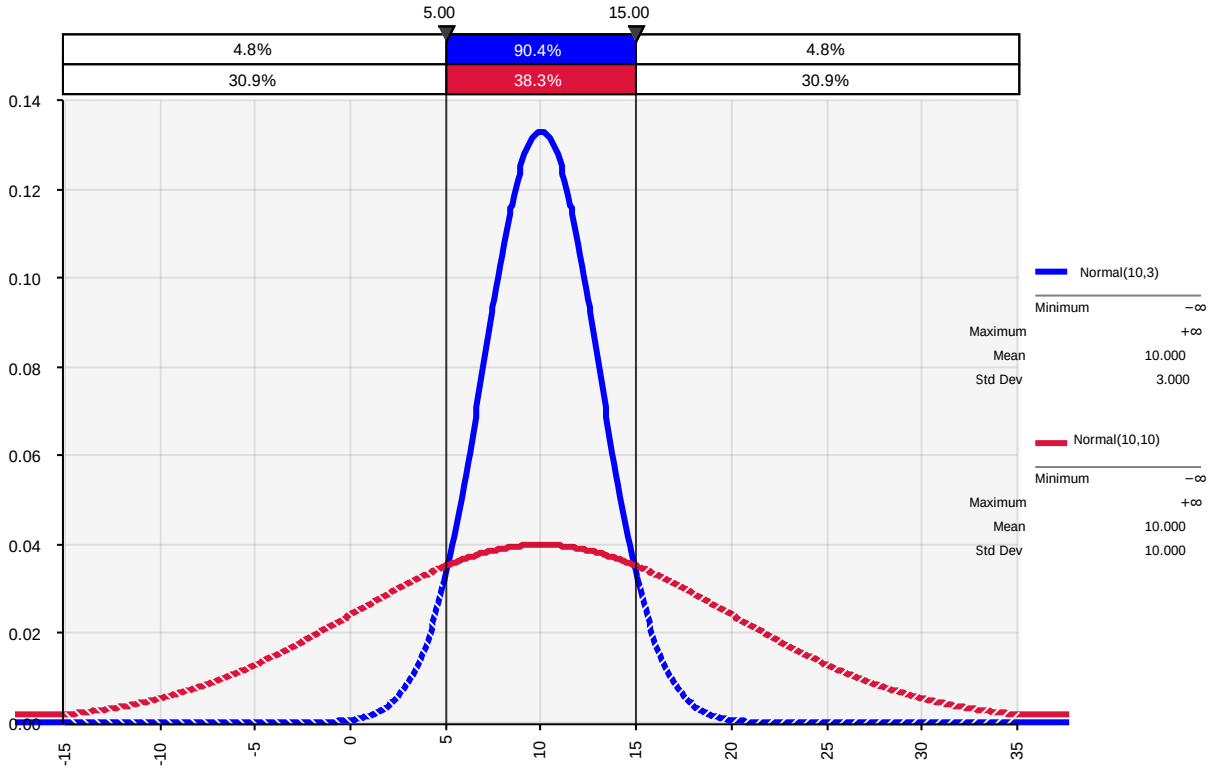
The RiskBernoulli function is a specific form of the RiskBinomial function with n=1.

Model Naming Convention

Type	Model Number	Line of Business	Model Prefix	Model Name
Stand-alone	01	Gas Ops	GAS	Transmission Pipeline Failure - Rupture with Ignition
	02	Gas Ops	GSO	Failure to Maintain Capacity for System Demands
	03	Gas Ops	MCDS	Measurement and Control Failure - Release of Gas with Ignition Downstream
	04	Gas Ops	MCFAC	Measurement and Control Failure - Release of Gas with Ignition at M&C Facility
	05	Gas Ops	DMSCB	Release of Gas with Ignition on Distribution Facilities- Distribution Cross-bore
	06	Gas Ops	CPFAC	Compression and Processing Failure – Release of Gas with Ignition at Manned Processing Facility
	07	Gas Ops	DMS	Release of Gas with Ignition on Distribution Facilities- Non-Cross-bore
	08	Gas Ops	STO	Natural Gas Storage Well Failure - Loss of Containment with Ignition
	09	Electric Ops	DIST	Distribution Overhead Conductor Primary
	10	Electric Ops	TRANS	Transmission Overhead Conductor
	11	Electric Ops	WILD	Wildfire
	12	Generation	NUC	Nuclear Operations and Safety - Core Damaging Event
	13	Generation	HYD	Hydro System Safety - Dams
	14	Safety and Health	CONSAFE	Contractor Safety
	15	Safety and Health	EMPSAFE	Employee Safety
	16	Safety and Health	MVS	Motor Vehicle Safety
	17	Safety and Health	FFD	Lack of Fitness for Duty Program Awareness
	18	IT	CYB	Cyber Attack
	19	IT	INSIDER	Insider Threat
Cross-Cutting	20	ERIM	ERIM	Records and Information Management
	21	HR	SQWF	Skilled and Qualified Workforce
	22	Strategy and Policy	CR	Climate Resilience

Distributions with the same mean but different tails

Example of how two curves with the same mean =10 but different tails (effected by the std deviation) may result in different decisions. The blue curve with a smaller tail value will have a much higher probability of returning a value between 5 and 15 (~90%) whereas the red curve with the same mean but larger tail value has a lower probability of returning between 5 and 15 (~38%).



	Blue	Red
Mean	10	10
Std Dev	3	10
90% Tail	15.28	27.57
Probability of returning >5 and <15	90.4%	38.3%

Safety Culture
(RAMP Chapter C)

Todd Hohn, Safety and Health (S&H)

12/15/17

Our Mission

To safely and reliably deliver affordable and clean energy to our customers and communities every single day, while building the energy network of tomorrow.

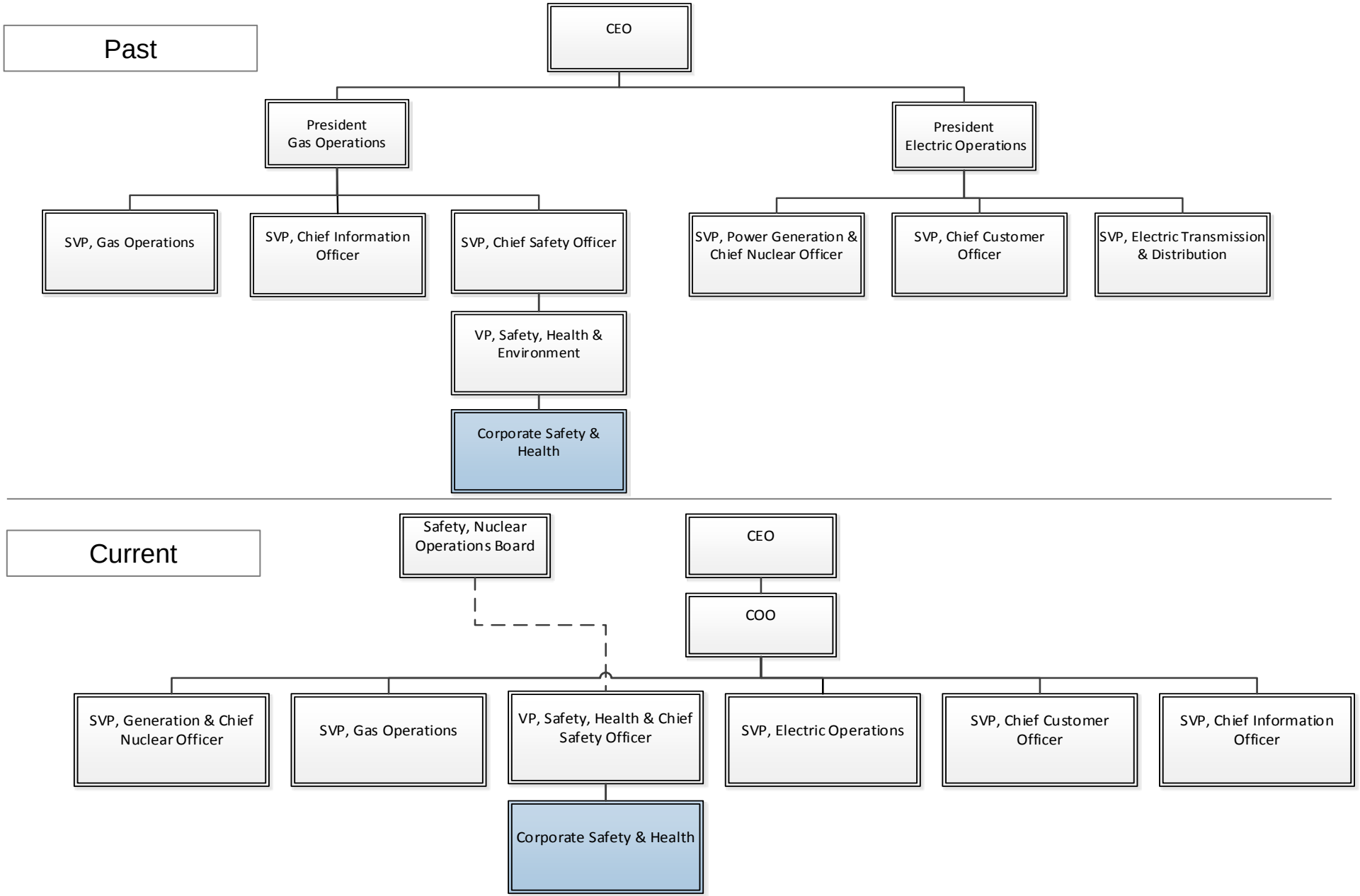
Our Vision

With a sustainable energy future as our North Star, we will meet the challenge of climate change while providing affordable energy for all customers.

Our Culture

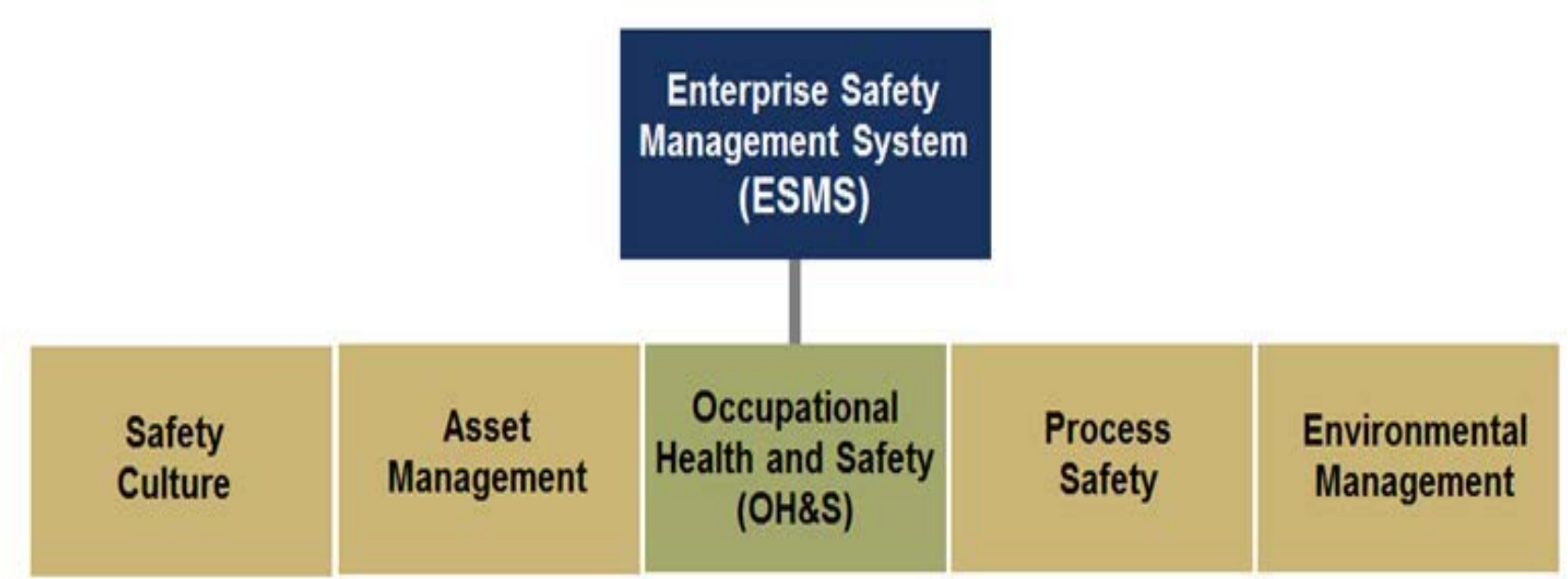
- **We put safety first.**
- **We are accountable. We act with integrity, transparency and humility.**
- **We are here to serve our customers.**
- **We embrace change, innovation and continuous improvement.**
- **We value diversity and inclusion. We speak up, listen up and follow up.**
- **We succeed through collaboration and partnership. We are one team.**

Service Delivery Model – Organizational Structure



Benefits Include:

- Integrated management of assets and risks
- Continuous improvement
- Comprehensive approach to safety



One PG&E Occupational Health & Safety Plan Summary

Improve safety and health performance and culture by using data analytics to drive targeted improvements in systems, processes, and communication

Employee Safety & Health

- Musculoskeletal Disorders, Sprains & Strains
- Safety Leadership Development / Safety Academy
- SIF Prevention
- Injury Management
- Health & Wellness

GOAL ALIGNMENT

- Achieve 1st Quartile LWD performance
- Reduction in DART rate
- Reduce severity of musculoskeletal disorders
- Reduce percentage of workforce unavailable due to health
- Expand safety education beyond current workshops

Contractor Safety

- Standardized Training
- Field Observations and Safety Performance Reviews
- Standardized Safety Plan and JSAs

GOAL ALIGNMENT

- Achieve 80% of prime contractors with an "A" grade

Motor Vehicle Safety

- Vehicle Safety Technology
- Driver Training
- DriverCheck
- Driver Selection

GOAL ALIGNMENT

- Achieve 1st quartile preventable motor vehicle incidents performance

Safety Management System

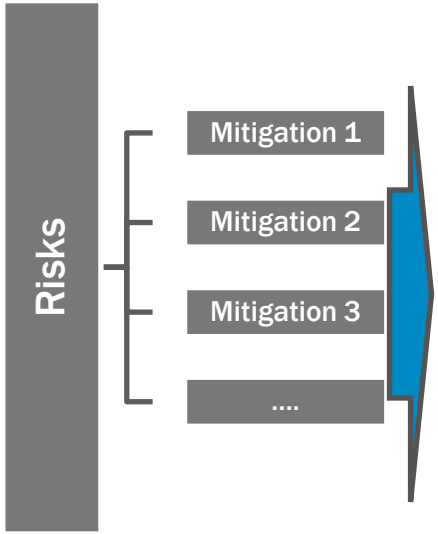
- Implement and Integrate Safety Management System

GOAL ALIGNMENT

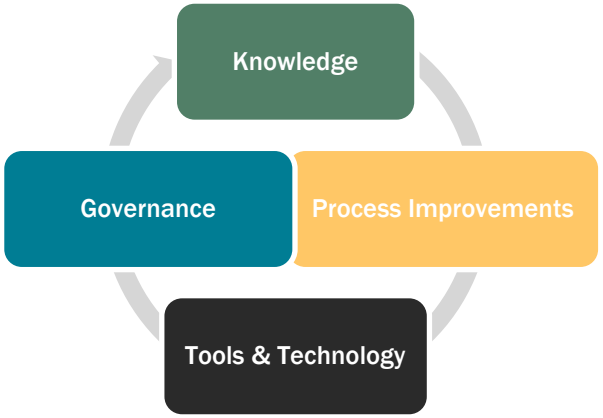
- Compliant with enterprise safety management system

Organizational Culture and Governance

Session D



Risk Assessment Mitigation Phase (RAMP)



One PG&E Occupational Health & Safety Plan

- Musculoskeletal Disorder
- Injury Management
- SIF Prevention
- Motor Vehicle Safety
- Workforce Unavailable Due to Health
- Contractor Safety
- Integrated Health & Safety
- Communications
- Safety Leadership
- Analytics & Dashboards
- Benchmarking
- Safety Management System

Transmission – Gas Pipeline Transmission Rupture with Ignition (Chapter 1)

RAMP Presentation

Gas Operations
Christine Cowsert
December 15, 2017

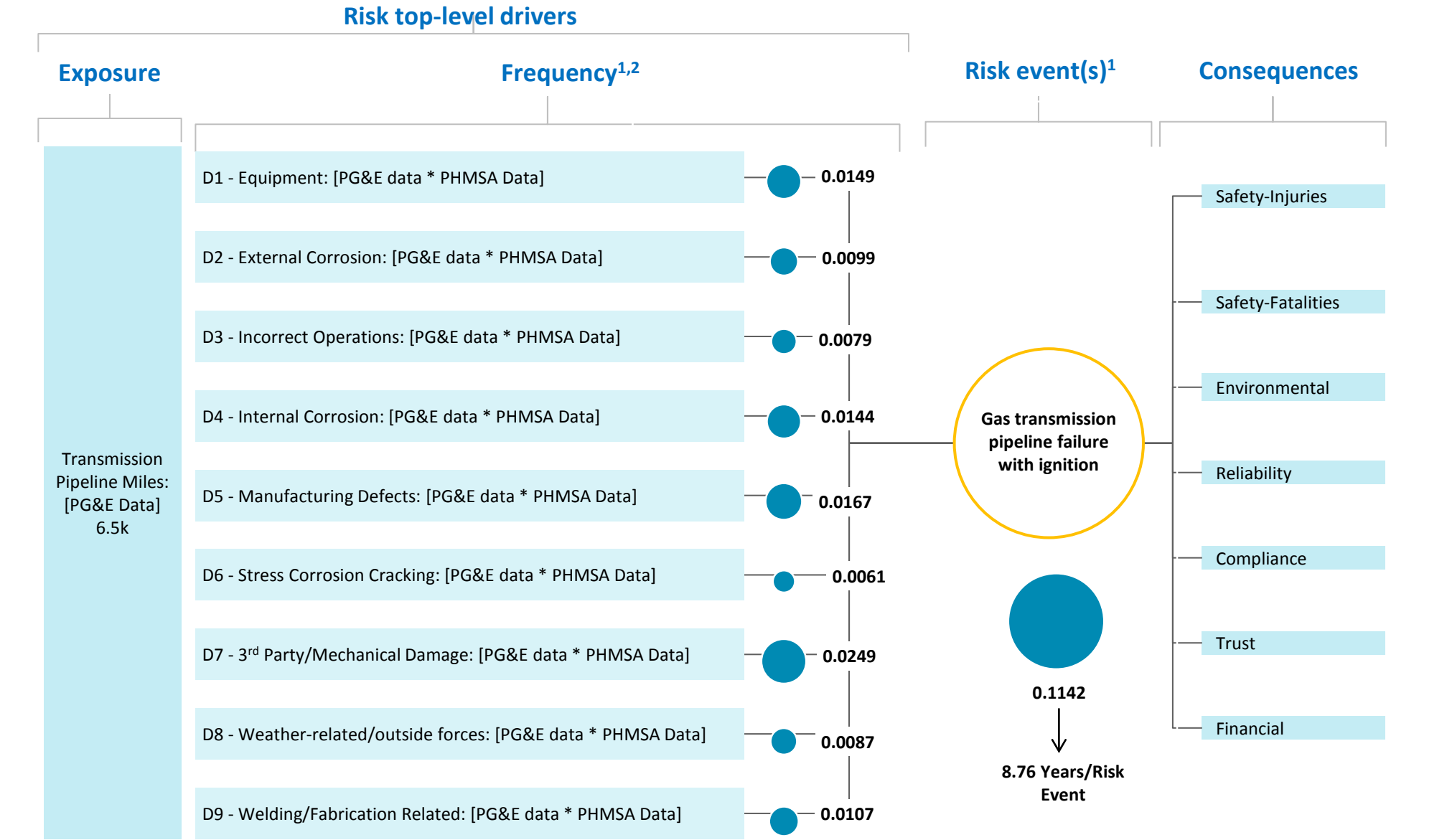
- **Risk Description**: Rupture of a transmission pipeline resulting in loss of containment and/or uncontrolled gas flow leading to ignition with potential public safety issues, prolonged outages, property damages and/or significant environmental damage.

- PG&E identified nine risk drivers based on American Society of Mechanical Engineers (ASME) B31.8S standard. These drivers are listed below:

    - Third-Party/Mechanical Damage
    - External Corrosion
    - Internal Corrosion
    - Stress Corrosion Cracking
    - Equipment Related
    - Manufacturing Related Defects
    - Welding/Fabrication Related
    - Incorrect Operations
    - Weather Related/Outside Forces

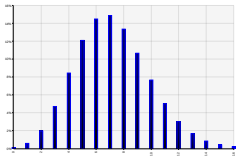
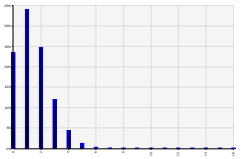
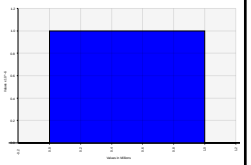
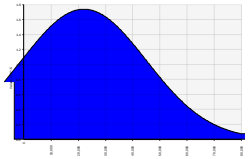
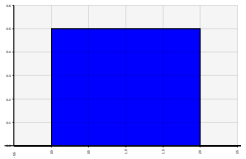
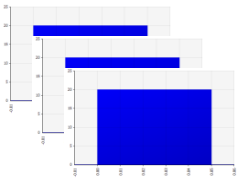
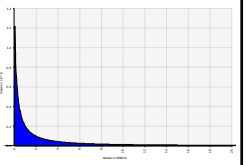
The exposure for the risk, frequency drivers for the risk as well as the probability of a risk event related to each risk driver are discussed in the following slide.

01 – GAS – Gas Transmission Pipeline Failure with Ignition – Year 1

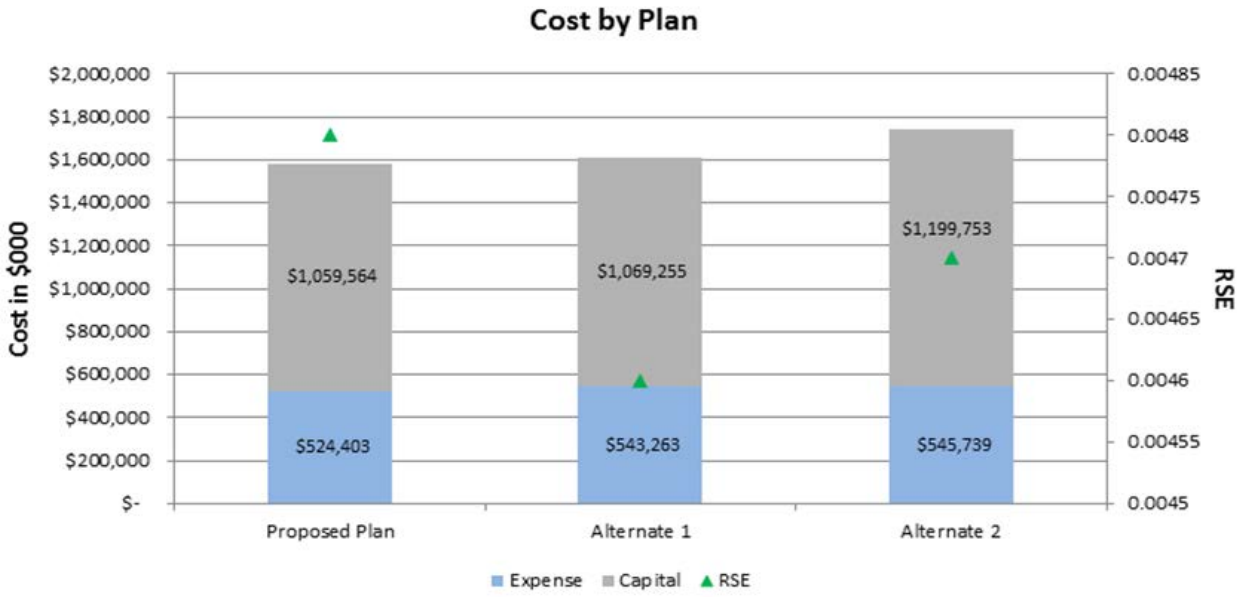


[1]Values displayed are means of each distribution and are in the units of events/year. Driver frequencies are summed to obtain the Risk event frequency.
[2]Drivers are modeled using Poisson and Binomial distributions.

Bowtie – Right Side (Consequence)

	Safety-Injuries	Safety-Fatalities	Environmental	Reliability	Compliance	Trust	Financial
Source	PHMSA	PHMSA	PG&E Data	PG&E Data	NA	PG&E Data and SME Input	PHMSA
Consequence	Percent of onshore, ignited incidents with injury or fatality=13.3% Mean=7.2 (Poisson) 	Percent of onshore, ignited incidents with injury or fatality=13.3% Mean=1.5 (Poisson) 	Min=$0 Max=$1M (Uniform) 	System likelihood of customer outage =12% x Customers (Normal): Ave=22k Std Dev=23k  x Customer minutes (Uniform): Min=0 days *24*60 Max=2 days *24*60 		Dependent on Safety outcomes. If there are any fatalities= High severity brand favorability change If there are injuries without fatalities, 50/50 chance of Low or Severe High severity=12-20% Severe=5-5-12% Low=0-5% (Uniform) 	Ave=$8.6M Std Dev=$61.2M (Lognormal) 
Outcome -TA-NU[1]	1.06	0.22	$ 565,851	6,299,387		2.0%	$ 9,685,119
Outcome -TA-MARS[2]	0.29	5.94	0.06	15.75		9.78	5.81
						MARS Total	**37.62**

[1]Ave of Year 1-6 Tail Ave outcomes in Natural units
[2]Ave of Year 1-6 Tail Ave outcomes in MARS units



Mitigation	Tail Average Risk Spend Efficiency (MARS Units/$1M)	Expected Value Risk Spend Efficiency (Units/$1M)	Proposed Plan	Alternate 1	Alternate 2
In-Line Inspection **(991 miles)**	0.0049	0.0005	X	X	
In-Line Inspection **(1,104 miles)**	0.0060	0.0007			X
Hydrostatic Testing **(107.9 miles)**	0.0052	0.0006	X		
Hydrostatic Testing **(177.9 miles)**	0.0049	0.0005		X	X
Vintage Pipe Replacement **(9.83 miles)**	0.0012	0.0001	X	X	
Vintage Pipe Replacement **(14.9 miles)**	0.0009	0.0001			X
Valve Automation **(191 miles)**	0.0152	0.0009	X	X	
Valve Automation **(164.7 miles)**	0.0110	0.0006			X
Shallow and Exposed Pipe **(4.2 miles)**	0.0008	0.0001	X		
Shallow and Exposed Pipe **(6 miles)**	0.0008	0.0001		X	X

- Use PG&E data instead of industry data, when we can, to improve conclusions from risk quantification. This risk model was updated with PG&E historical leak data. However, given the small sample size of pipeline ruptures at PG&E, industry data was used to determine rupture and ignition likelihoods. This presents the opportunity to advance quantification in order to account for segment level data unique to PG&E.

- Refine model inputs for reliability, environmental, compliance and financial impacts. The modeling effort was primarily focused on safety and broad assumptions had to be made for the other consequence categories.

- Consider PG&E can align risk models with work plan and forecast development.

- Review new industry data reporting a significant increase in equipment-related drivers, which may be a result of the change in PHMSA reporting thresholds rather than an actual increase in equipment related defects.

- Perform further sensitivity analysis and calibration of model outputs. For example, given the design of the models, Valve Automation program has the highest RSE among the mitigations. This is unexpected since valve automation, unlike other mitigations, does not prevent the event from occurring.

Release of Gas with Ignition on Distribution Facilities – Non-Cross Bore (Chapter 7)

RAMP Presentation

Gas Operations
Christine Cowsert
December 15, 2017

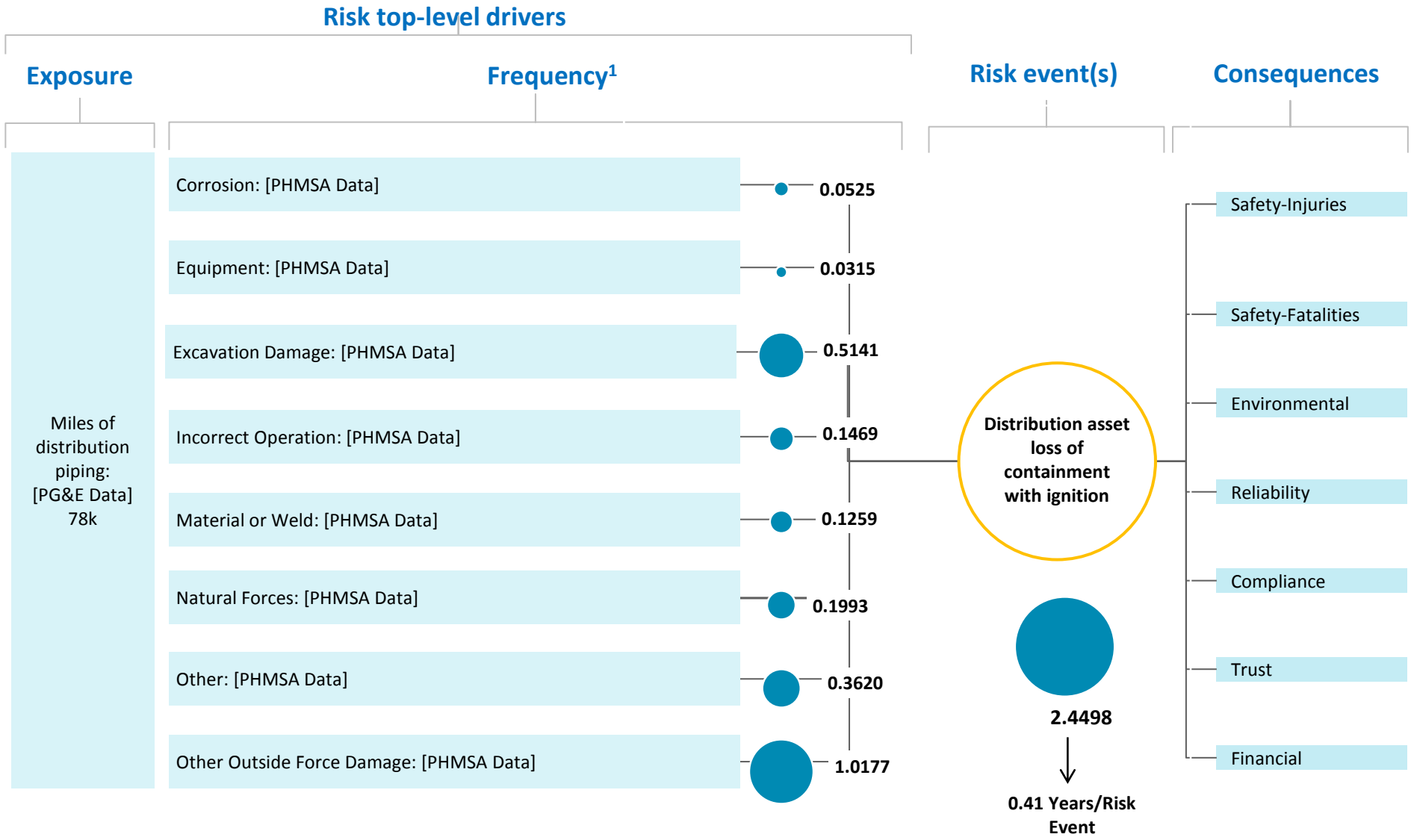
- **Risk Description**: Rupture of a distribution pipeline which may result in loss of containment and migration and ignition of gas, leading to a safety impact or property damage

- PG&E identified eight risk drivers based on 49 CFR Part 192, Subpart P. These drivers are listed below:

    - Corrosion
    - Equipment Related
    - Excavation Damage
    - Incorrect Operations
    - Material/ Weld
    - Natural Forces
    - Other
    - Other Outside Force Damage

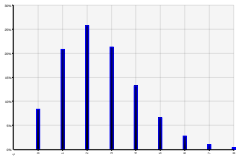
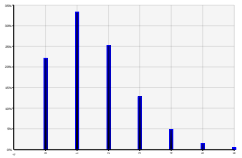
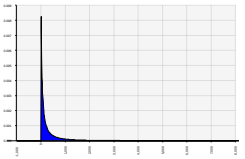
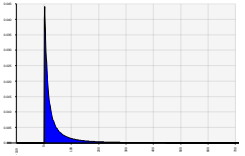
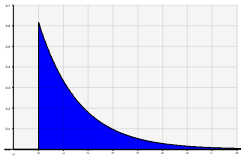
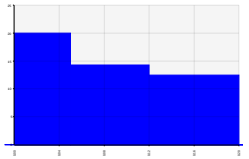
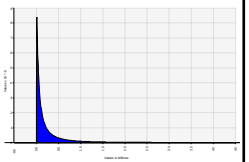
The exposure for the risk, frequency drivers for the risk as well as the probability of a risk event related to each risk driver are discussed in the following slide.

Bowtie – Left Side (Year 1)

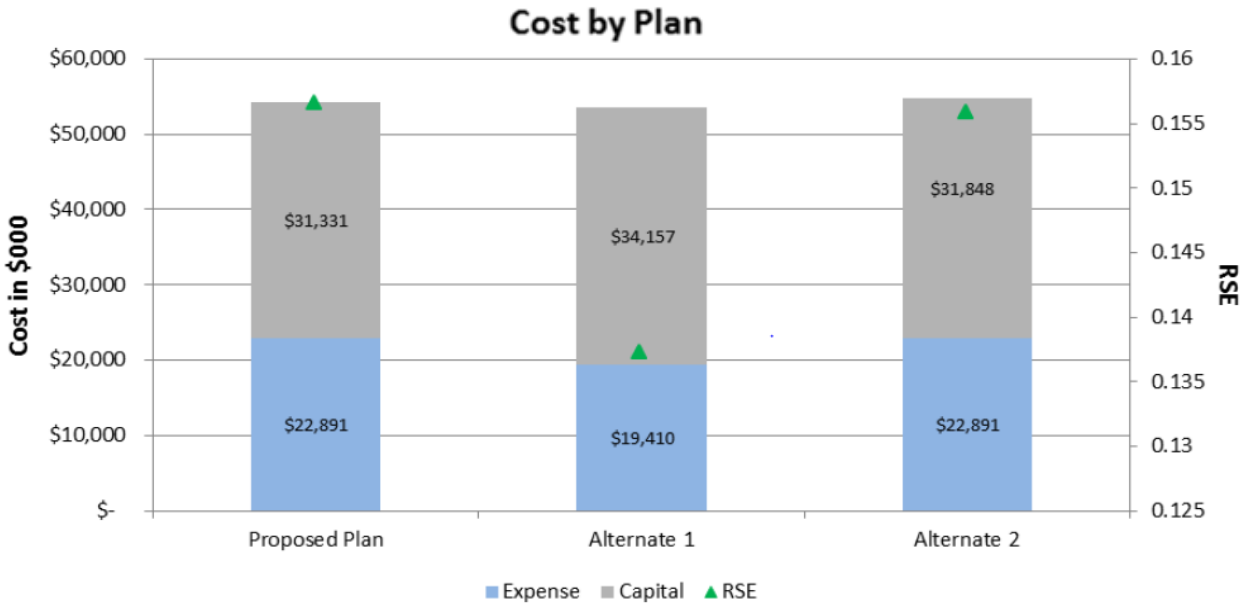


[1]Values displayed are means of each distribution and are in the units of events/year. Driver frequencies are summed to obtain the Risk event frequency.
[2]Drivers are modeled using Poisson and Binomial distributions.

Bowtie – Right Side (Consequence)

	Safety-Injuries	Safety-Fatalities	Environmental	Reliability	Compliance	Trust	Financial
Source	PHMSA	PHMSA	PHMSA	PG&E Data	NA	PG&E Data and SME Input	PHMSA
Consequence	Percent of ignition events with injury=28% Mean=2.5 (Poisson) 	Percent of ignition events with fatality=10% Mean=1.5 (Poisson) 	Ave=594MCF Std Dev=2,690MCF Ave cost of Carbon[3]=$13 /tonne CO2 (Lognormal) 	Customers Ave customers affected=57 Std Dev=166 (Lognormal)  Ave duration of outage=1.62 hours*24*60 (Exponential) 		Dependent on Safety outcomes. If there are any fatalities= High severity brand favorability change If there are injuries without fatalities, 50/50 chance of Low or Severe High severity=12-20% Severe=5-5-12% Low=0-5% (Uniform) 	Ave=$381k Std Dev=$1.3M (Lognormal) 
Outcome-TA-NU[1]	7.32	2.86	$5,600	7,140,130		17.63%	$4,837,902
Outcome-TA-MARS[2]	2.00	77.92	0.00	17.85		88.16	2.90
						MARS Total	**188.84**

[1]Ave of Year 1-6 Tail Ave outcomes in Natural units
[2]Ave of Year 1-6 Tail Ave outcomes in MARS units
[3]To convert MCF to tonne multiply by ~52/1000



Mitigation	Tail Average Risk Spend Efficiency (MARS Units/$1M)	Expected Value Risk Spend Efficiency (Units/$1M)	Proposed Plan	Alternate 1	Alternate 2
DIMP Emergent Work **(14 miles)**	0.0014	0.0015	X	X	X
New Valve Installations **(9,024 miles)**	0.2141	0.0329	X		
Enhanced Cathodic Protection Survey & Unprotected Main Program **(8,000 miles)**	0.0891	0.0974	X		X
Electrically Connected Isolated Steel Service **(1,800 miles)**	0.0353	0.0376	X		X
Enhanced Cathodic Protection Survey & Unprotected Main Program **(6,000 miles)**	0.0993	0.1058		X	
Electrically Connected Isolated Steel Service **(1,680 miles)**	0.0271	0.0296		X	
New Valve Installations **(8,992 miles*)**	0.1811	0.0270		X	
New Valve Installations **(8,992 miles)**	0.2126	0.0326			X

***Program would be on an accelerated pace and complete by 2021.**

Next Steps:

- Use PG&E data instead of industry data, when we can, to enable actionable conclusions from risk quantification. For example, PG&E's historical leak and excavation damage data are possible areas of further analysis for inclusion.

- Refine model inputs for reliability, environmental, compliance and financial impacts. The modeling effort was primarily focused on safety and broad assumptions had to be made for the other consequence categories.

- Consider how GO can align risk models with work plan and estimate development.

- Evaluate risk reduction metrics further and identify if there are additional metrics that can be defined to measure risk reduction.

- Include additional rigor on alternative plan creation and evaluation given growing institutionalized knowledge of the risk model.

- Continue evolution of the model to better reflect risk reduction and mitigation effectiveness for the mitigations.

Similarities and Differences between Transmission & Distribution Pipeline Risks

Risk Overview:

- Risk Drivers are similar but differences exist because Transmission follows the ASME B31.8S standard whereas Distribution follows 49 CFR Part 192, Subpart P.

- The Distribution pipeline risk does not include a specific scenario of a rupture with ignition due to Cross Bores given the unique nature of cross bores which involves migration of gas through sewer systems into homes.

Bowties:

- Transmission risk used PG&E historical leak data and PHMSA major incident reporting data to determine event frequencies whereas Distribution risk used PHMSA data and use of PG&E data is identified as a next step for the risk.

- The risk event frequency output shows that Distribution risk is more frequent (2.5 events per year) than the Transmission risk (1 event every 9 years). This outcome seems reasonable since Distribution events are more frequent and may lead to severe consequences depending on the location of the event, presence of people and various other factors.

Consequences:

- Transmission and Distribution risks used a combination of PG&E data, PHMSA data, and SME Input to quantify the consequence categories.

- The outcomes in safety and trust impacts are higher for the Distribution risk compared to the Transmission risk where the impacts for environmental and financial are higher.

Risk Assessment and Mitigation Phase (RAMP) Wildfire (Chapter 11)

Dave Gabbard, Electric Operations

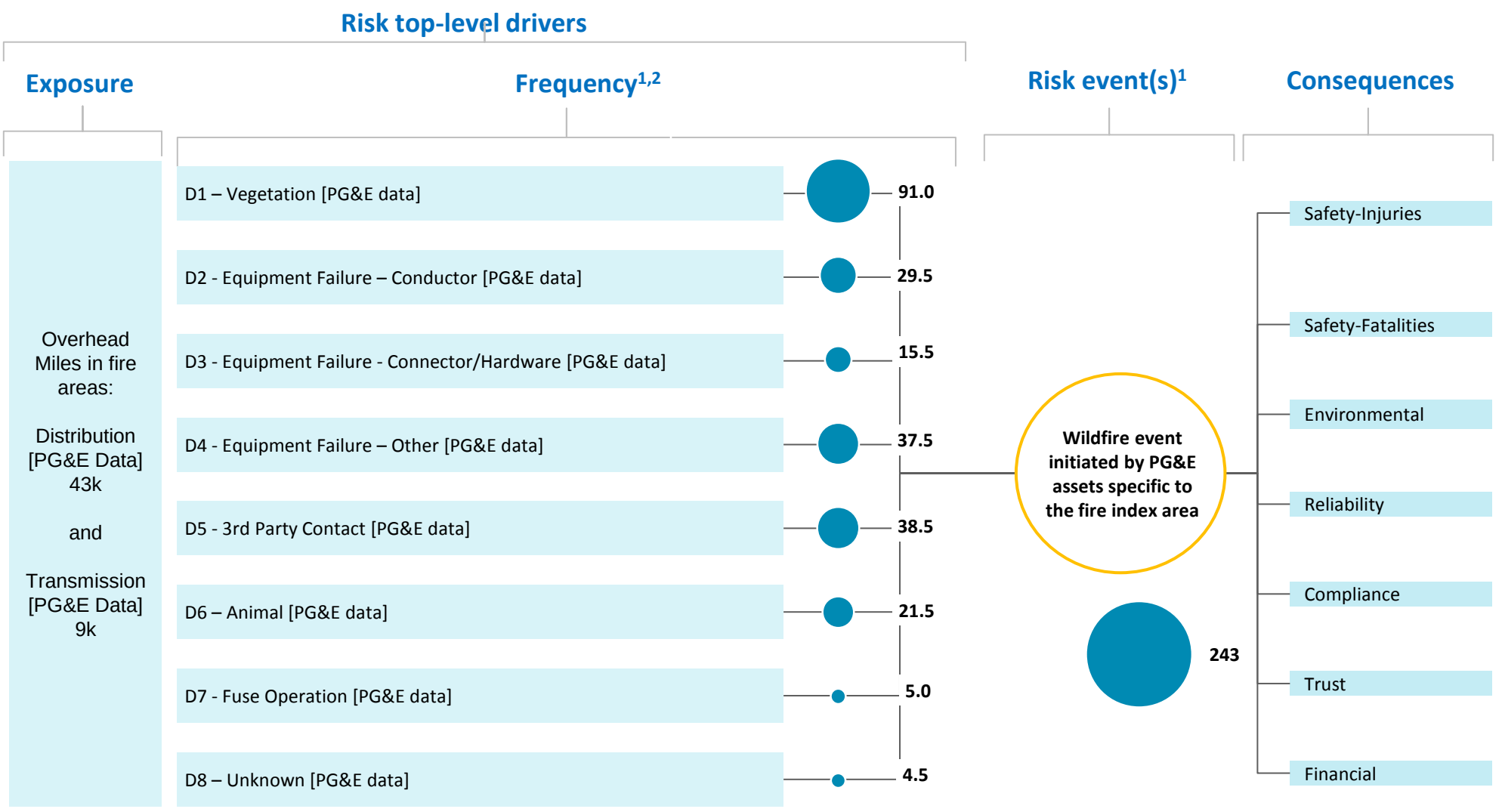
12/15/17

Overview of the Risk

- The risk posed by wildfires has increased in PG&E's service area as a result of an extended period of drought, bark beetle infestations in the California forest and wildfire fuel increases resulting from record rainfall following the drought, among other environmental factors.
- Of the 20 most destructive wildfires published by CAL FIRE, 35% (7) have occurred in the last three years[1]
- Managing wildfire risk[2] is a top priority for PG&E; the annual total investment in 2016 for all wildfire risk related controls was approximately $750 million. Most of this investment, about $435 million, was focused on PG&E's biggest wildfire risk driver—Vegetation.

1. 20 Most destructive wildfires published by CAL FIRE; http://www.fire.ca.gov/communications/downloads/fact_sheets/Top20_Destruction.pdf
2. Wildfire Risk description: PG&E assets may initiate a wildland fire that endangers the public, private property, sensitive lands, and/or leads to long-duration service outages

Quantitative Risk Assessment



1. Values displayed are means of each distribution and are in the units of events/year. Driver frequencies are summed to obtain the Risk event frequency.
2. Drivers are modeled using Poisson distributions.

Quantitative Risk Assessment

Inputs to the Risk Model - Exposure

- Measured in distribution and transmission overhead circuit miles in Fire Index Areas
  - The Fire Danger Rating System was created by federal and state agencies to enable area based rating of fire danger based on local weather conditions. The area of PG&E service territory that is not fire indexed has significantly lower fire risk and is not included in the model.
- Risk is not equal on all miles of overhead line. Frequency and impact varies based on geography, climate, type of line, equipment on line, and conditions around the line

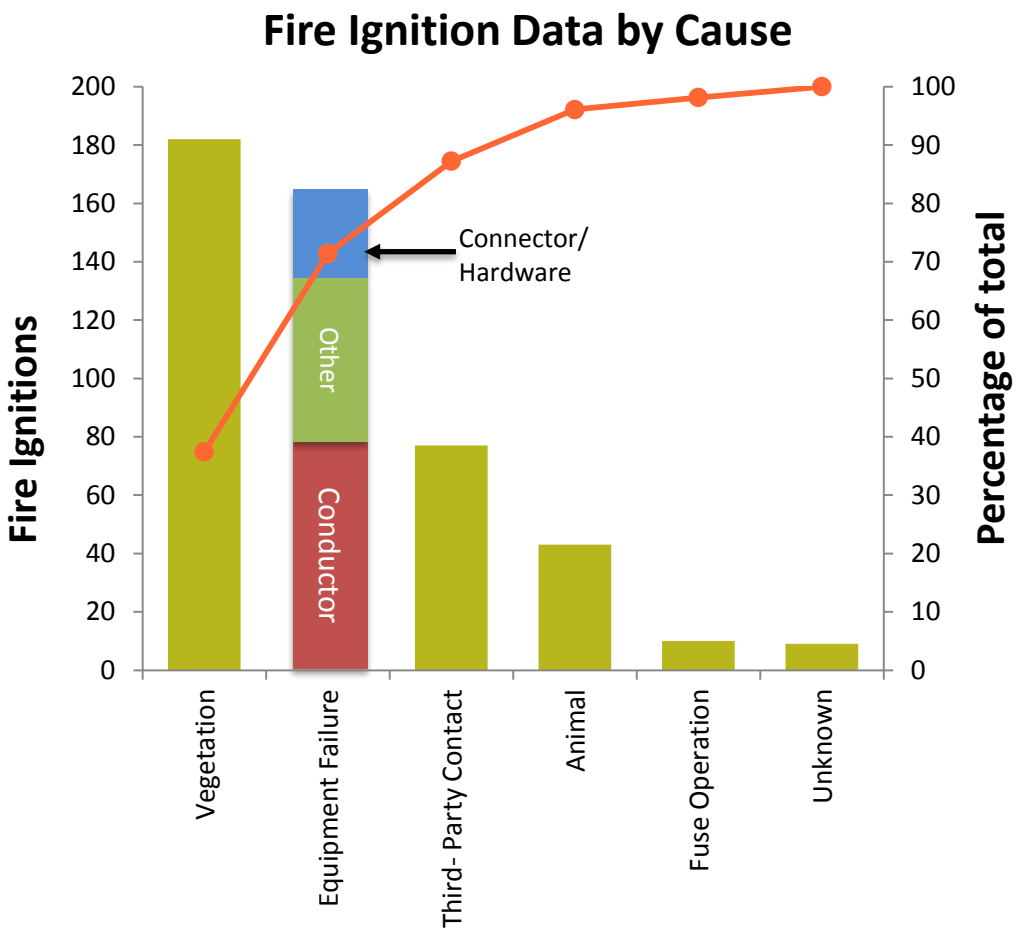
	Transmission	Distribution
Wildfire risk model circuit miles (fire index areas)	9,244	43,893
All circuit miles	18,352	82,088

Quantitative Risk Assessment

Inputs to the Risk Model - Drivers

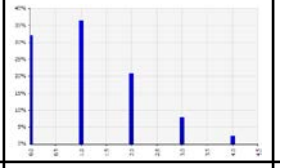
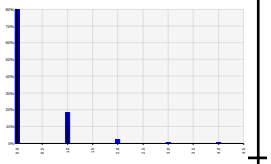
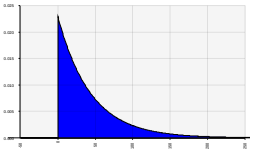
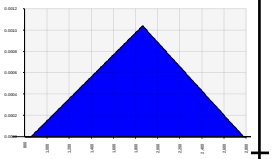
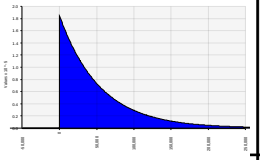
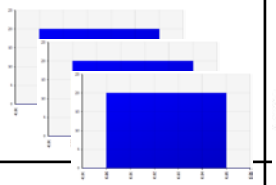
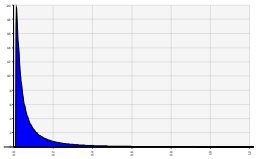
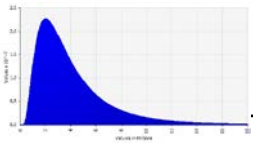
Driver Counts (2015-2016) - Source: PG&E Fire Ignition data in Fire Index Areas

	Count*	Percent
Vegetation	182	37%
Equipment Failure - Conductor	59	12%
Equipment Failure - Connector/Hardware	31	6%
Equipment Failure - Other	75	15%
Third- Party Contact	77	16%
Animal	43	9%
Fuse Operation	10	2%
Unknown	9	2%



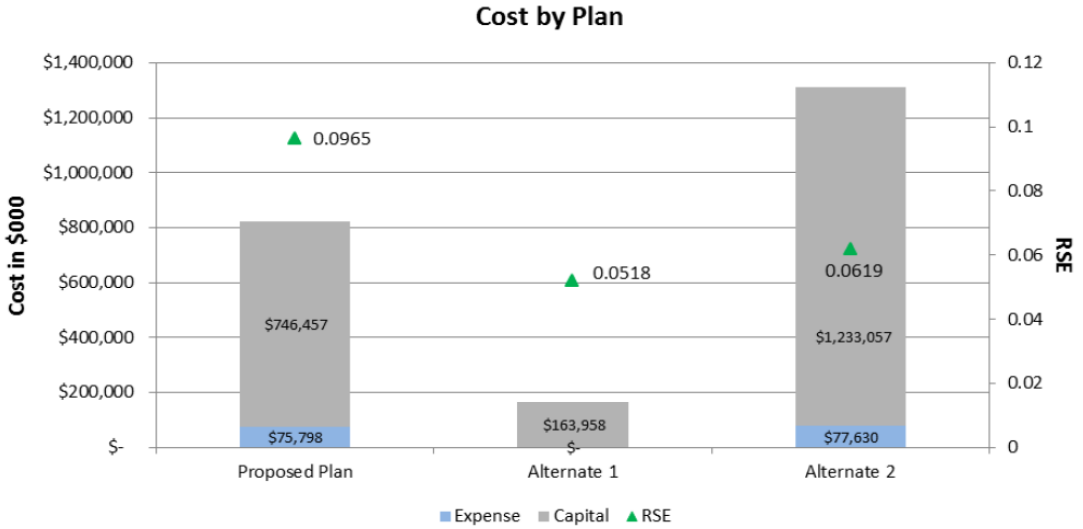
*two years of data (2015 and 2016)

Quantitative Risk Assessment

	Safety-Injuries	Safety-Fatalities	Environmental	Reliability	Compliance	Trust	Financial
Source	Calfire and NFIRS Data	Calfire and NFIRS Data	Calfire, PG&E & Pacific Union settlement Data	PG&E Data	NA	PG&E Data	PG&E and Claims Data
Consequence Distributions	Percent of wildfire events with an injury = 0.51% Percentage of events with injury or fatality = 0.62% Mean=1.14 (Poisson) 	Percent of wildfire events with a fatality = 0.10% Percentage of events with injury or fatality = 0.62% Mean=0.23 (Poisson) 	Ave # acres burned/wildfire event = 44 acres (exponential)  x Cost per acre: Min = $855/acre Ave = $1,865/acre Max = $2,778/acre (Triangular) 	Percentage of events resulting in outage = 95% Ave = 54k customer minutes (Exponential) 		Dependent on Safety outcomes. If there are any fatalities= High severity brand favorability change If there are injuries without fatalities, 50/50 chance of Low or Severe High severity=12-20% Severe=5-5-12% Low=0-5% (Uniform) 	Property: destroyed: Ave=0.392 Std Dev=1.454 Shift=0.018 (Lognormal) x Cost/property destroyed=$778k  Compensatory claims from safety events: Ave=$4.1M Std Dev=$3.3M Shift=$66k (Lognormal) 
Outcome-TA-NU[1]	5.89	1.78	$27,649,728	14,791,813		18.5%	$125,436,835
Outcome-TA-MARS[2]	1.61	48.54	2.76	36.98		92.43	75.26
						MARS Total	**257.58**

[1]Ave of Year 1-6 Tail Ave outcomes in Natural units
[2]Ave of Year 1-6 Tail Ave outcomes in MARS units

Proposed Mitigation Plan & Alternatives



Mitigation	Expected Value Risk Spend Efficiency Score (MARS Units/$1M)	Tail Average Risk Spend Efficiency Score (MARS Units/$1M)	Proposed Plan	Alternate 1	Alternate 2
Fuel Reduction and Powerline Corridor Management	0.9496	0.7977	X		X
Overhang Clearing	0.3762	0.3160	X		X
Wildfire reclosing operation program	0.1007	0.0841	X	X	X
Non-Exempt Surge Arrester Replacement	0.0470	0.0388	X	X	X
Targeted Underground Conversion	0.0058	0.0048			X
Targeted Conductor Replacement	0.0049	0.0041	X		X
Avian Mitigation for Wildfire risk	0.0016	0.0013			X
Targeted Pole Replacement	0.0002	0.0002			X

Lessons Learned and Next Steps

Lessons Learned:

- Quantification work for the RAMP models have improved our understanding of baseline risk and related data
- Risk Spend Efficiency developed from model provides high-level direction for most efficient mitigations for a particular risk
- The base model assumption is that risk drivers occur equally across the risk exposure (measured in circuit miles)
- The accuracy of effectiveness estimates vary widely however 'point estimates' are used in the model (some are more accurate and based on data, while some are SME based judgements)
- Risk reduction focuses on RAMP period and does not consider costs and benefits over the life of an investment

Next Steps:

- PG&E will monitor the implementation of the existing mitigation plan and refine assumptions about wildfire reduction effectiveness
- Further calibrate the tail-end outputs of the model against actual impacts of high impact fires that have occurred across California in recent years
- Revise model exposure to consider the increased number of ignitions, which occur per-distribution-circuit-mile, compared to transmission

Contractor Safety (RAMP Chapter 14)

Todd Hohn, Safety and Health (S&H)

12/15/17

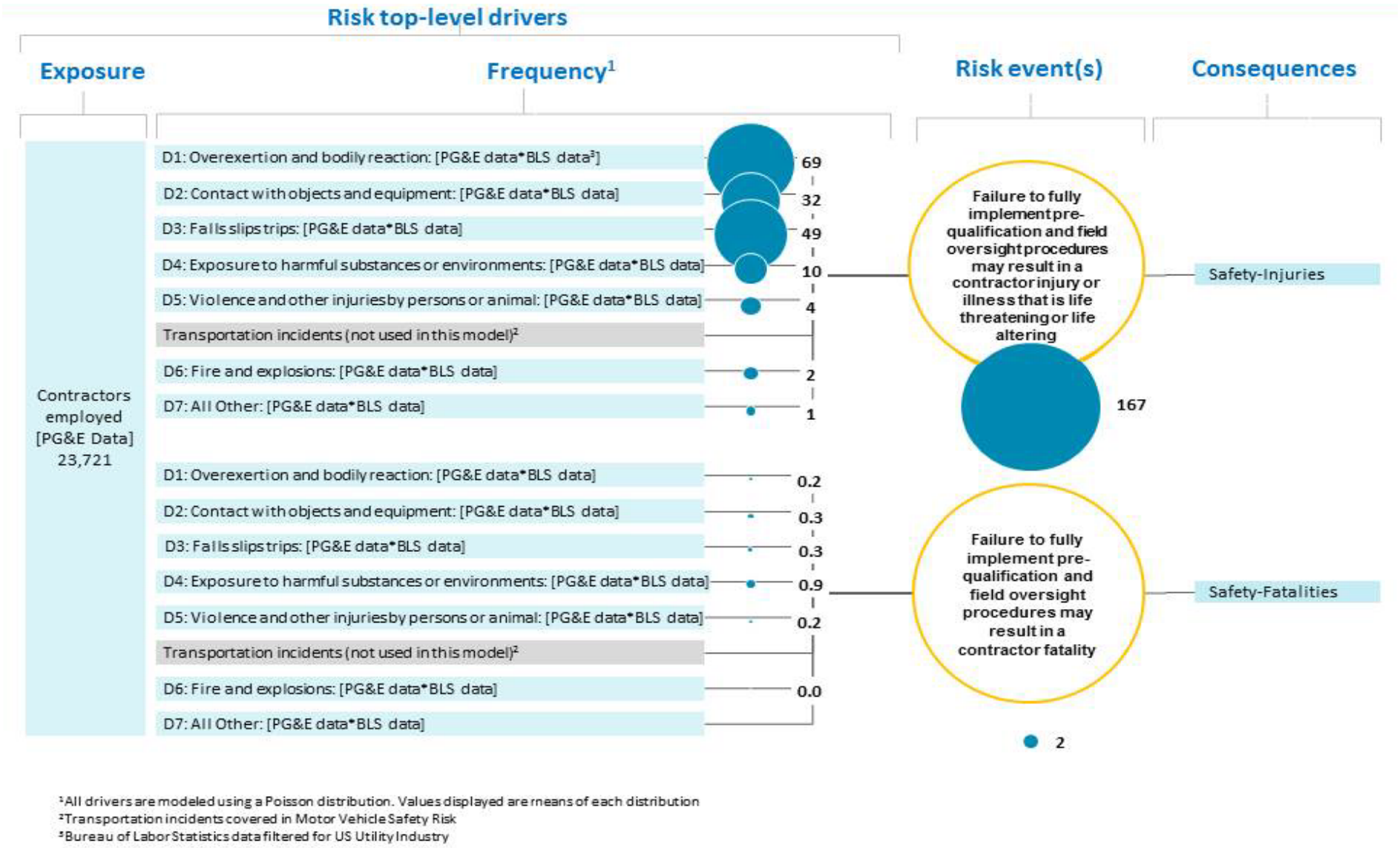
- Contractor Safety risk is the failure to identify and mitigate occupational exposures that may result in a contractor injury or illness that is fatal, life threatening or life altering.

- Pacific Gas and Electric Company (PG&E) had a monthly average of approximately 2,000 contract companies with approximately 24,000 contract employees in 2016 performing work for PG&E.

- The costs of not mitigating contractor safety include injuries, illnesses, fatalities, fines, and delays or disruptions in work flow.

- Their work included high risk exposures, such as high voltage, hazardous materials, heavy equipment, and fall hazards.

- The primary drivers of this risk include overexertion and bodily reaction, contact with objects and equipment, and falls/slips.



[1]All drivers are modeled using a Poisson distribution. Values displayed are means of each distribution
[2]Transportation incidents covered in Motor Vehicle Safety Risk
[3]Bureau of Labor Statistics data filtered for US Utility Industry

* Values represented are an annual average.

Four mitigation categories were created for RAMP with two (2) alternative plans:

- **Contractor Governance**
  - Develops a procedural framework for managing PG&E processes and the program requirements, with the goal of reducing contractor injuries through compliance with these mitigations.
  - Examples include: Safety observations through SafetyNet, Increase field oversight, enhance post-job performance evaluations for contractors

- **Contractor Knowledge**
  - Provides additional training and knowledge assessment of the program requirements for PG&E employees and contractors to support the reduction of injuries and fatalities resulting from contractor operations
  - Examples include: Web-based Training employees/contractors, additional safety training criteria for employees/contractors

- **Contractor Process Improvements**
  - Addresses program gaps by developing and implementing needed process improvements to close risk exposure gaps, supporting the reduction of contractor injuries resulting from contractor operations
  - Examples include: Standardizing templates for safety plans, supplier safety incentives, Review DMV records

- **Tools and Technology**
  - Provides tools and technology to support the reduction of contractor injuries resulting from contractor operations.
  - Examples include: ISNetworld (ISN) contractor badging, insurance certificate validation through ISN

- **Alternative Plan 1 –** Removes SOW development improvements strategy (M11B) from the Contractor Process Improvements mitigation.

- **Alternative Plan 2 -** In addition to the removal of SOW Enhancements (M11B), this plan removes the DMV records review

- Proposed Mitigation Plan was selected because of the potential return on investment identified in the RAMP model, providing the greatest risk reduction through the most effective use of resources.
- The mitigations costs are related to process improvements, technology enhancements and training.
- Contractor Knowledge (379.25) and Tools and Technology (315.52) had the highest risk spend efficiencies (RSE)
- Costs included in the chapter are controlled by Corporate Safety & Health.

- There is still work to be done in capturing and drilling down in the contractor injury, illness and fatality data.
- More data will need to be collected through ISN to obtain larger data sets of contractor injury, safety incident and fatality information to continue to drive the expected reductions in frequency of events.
- The ability to determine whether existing controls and the proposed mitigations have been effective in reducing risk and the occurrences of each driver will improve.
- PG&E will continue to enhance data collection process by further exploring ISN's capabilities and benchmarking with peer utilities to expand capability through new tools and techniques.

Cyber Attack (RAMP Chapter 18)

Joe Sagona, Cybersecurity

12/15/17

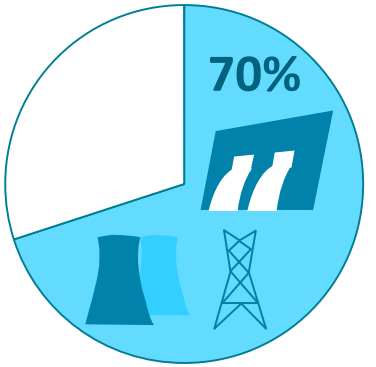
Risk and Key Takeaways

"A coordinated malicious attack targeted at PG&E's core business functions, resulting in a loss of control over information and systems used for gas, electric, and business operations."

- Cyber attacks are persistent and evolving
- Cyber attacks are different from other risks due to active adversaries
- We are strategically organized to address the risk
- Mitigation for this risk requires ongoing effort

The Threat is Persistent… and Evolving

64,199
Cyber security incidents occurred across **82 countries** and **20 industries** in 2015.



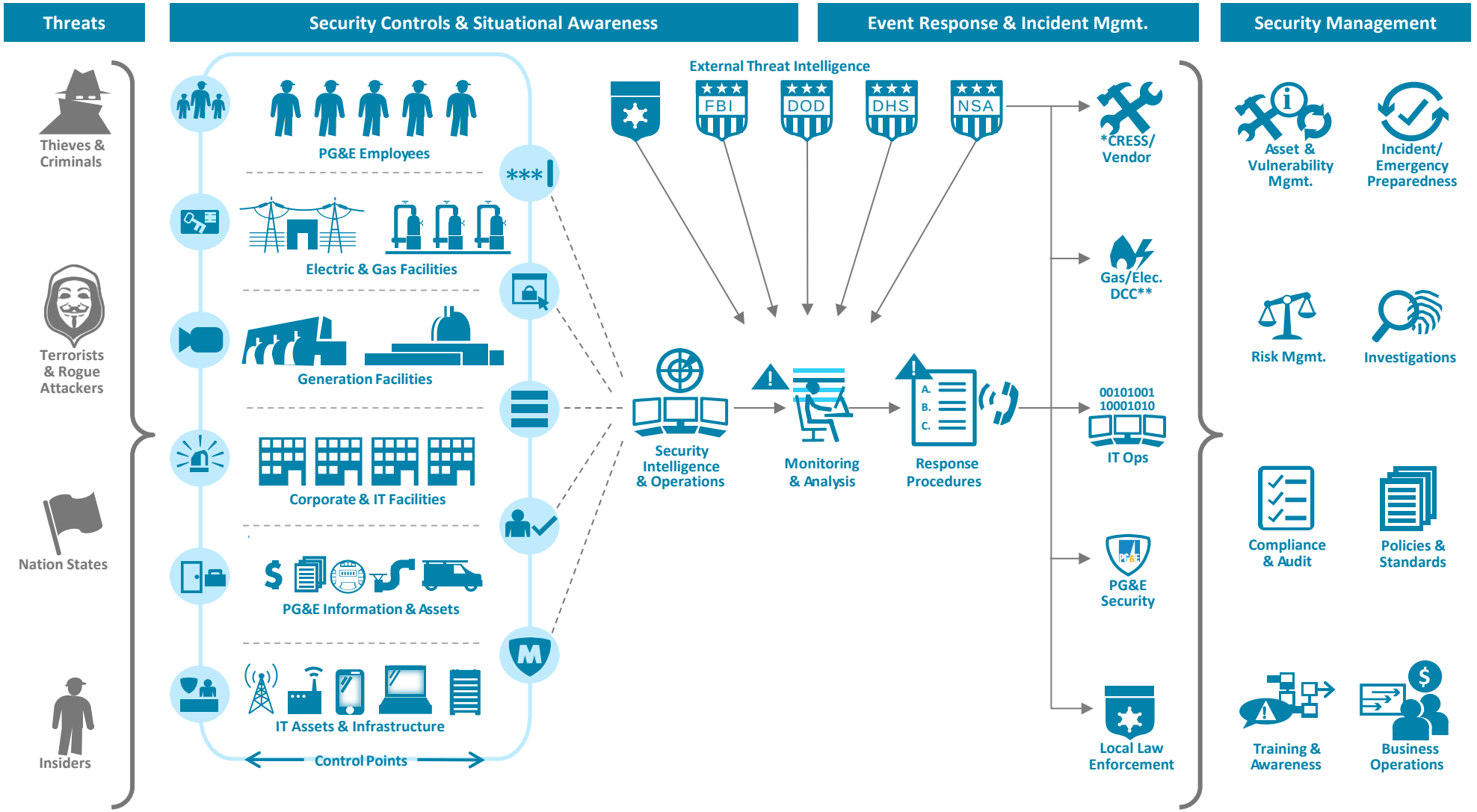
70% of the world's power, water, and critical infrastructure providers **reported a breach in the past year**, which led to a loss of confidential information or a disruption in operations.

2,260
Cyber breaches, with **confirmed data loss**, took place worldwide in 2015.

295
Critical infrastructure incidents were reported by U.S. companies in 2015.
The energy sector was the 2nd-most hacked, with 46 reported incidents.

12%
of these incidents (35 incidents) resulted in an intrusion into the company's control system.

Security Strategy Overview



*CRESS – Corporate Real Estate Strategy and Services
**DCC – Distribution Control Center

Cybersecurity Mission & Vision

OUR VISION:

To be recognized as a cutting-edge cybersecurity organization that employs the best professionals and leverages top-tier capabilities to safeguard California's gas and electric system

OUR MISSION:

Deliver and maintain an integrated program that safeguards PG&E's digital assets by:

- Identifying our cybersecurity risks and defining mitigating strategies
- Building, deploying, and operating effective security technologies and processes
- Proactively monitoring for, and responding to, cyber threats
- Engaging stakeholders in constructive dialogue about risk management

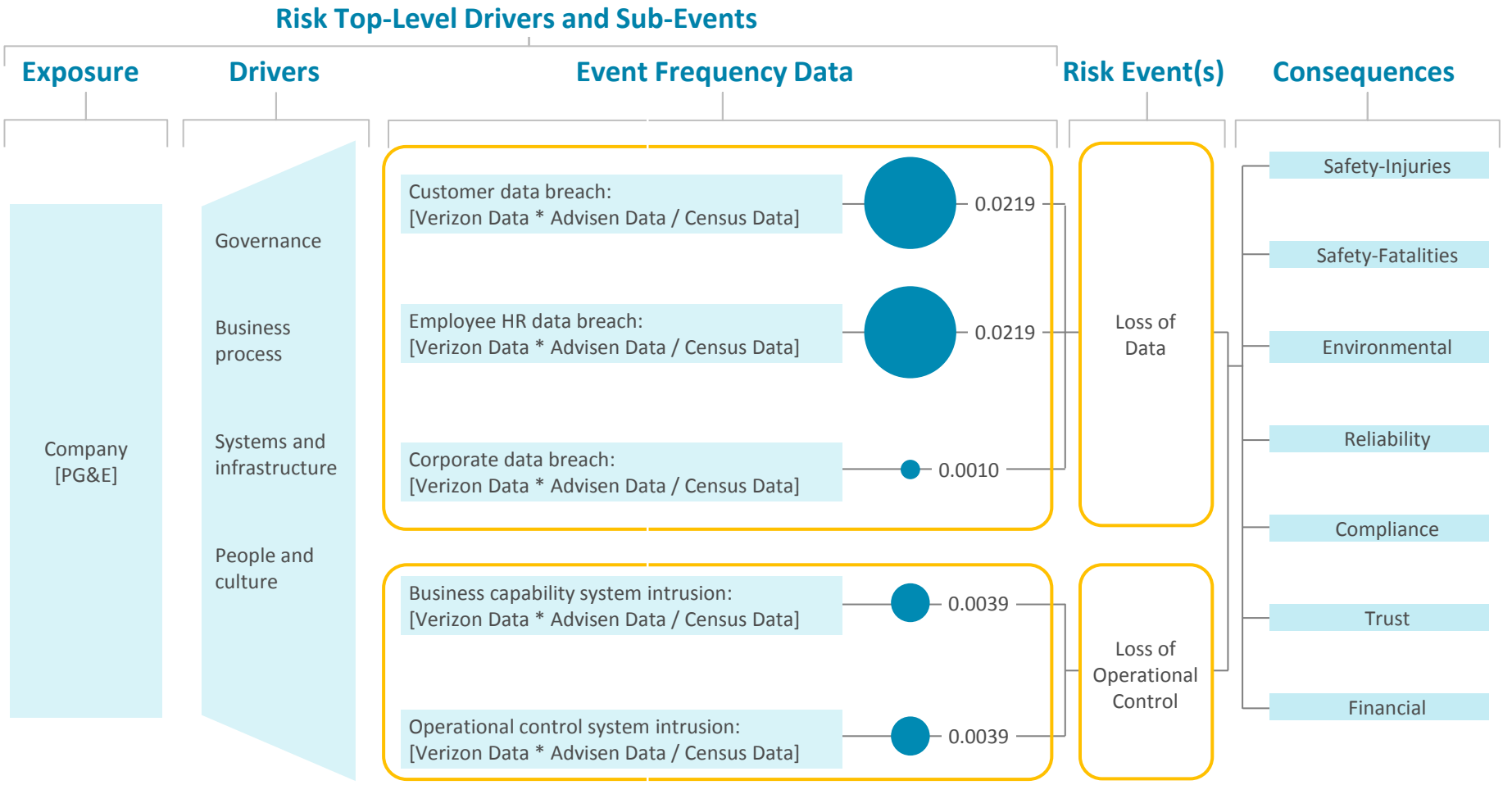
Key Organizational Components

Risk & Strategy	Cybersecurity Services	Security & Intelligence Operations Center	External Engagement.
Partner with each Line of Business to understand and strategically manage risk and related solutions	Implement and maintain core security technologies and services to manage vulnerabilities and support compliance	Provide cutting-edge security monitoring with in-house threat intelligence and monitoring, proactive incident analysis and response	Collaborate with industry and government to drive standards, frameworks, technologies and change, to align with internal PG&E strategies

Risk Description

A coordinated malicious attack purposefully targeted at PG&E's core business functions, resulting in a ***loss of control over information and systems*** *used for gas, electric, and business operations.*

Cyber Attack – Bow Tie



[1]All drivers are modeled using a Poisson distribution. Values displayed are means of each distribution.

Model Outputs

Model-driven Natural Unit Consequences of a Cyber Attack		
Attribute	Consequence*	Justification
Safety	0.76 - Injury 0.04 - Fatality	Safety-related events due to cyber attack are rare.
Environmental	$62k	Environmental events due to cyber attack are few in number and expected to be infrequent.
Reliability	11.5M Minutes	Loss of operational control would greatly impact our ability to deliver gas and electric services.
Compliance	$333k	Most compliance issues are independent of cyber attacks or potential cyber attacks.
Trust	4.48%	Loss of control and data loss events would erode customer confidence in PG&E.
Financial	$92M	Costs to recover from a cyber attack are expected to be substantial.

**Tail Average (90-100%) of the 6 years modeled in natural units*

Mitigations & Alternatives*

Identify

- Citizen Developer Models
- Third Party Security & Risk Management
- Identity Access Mgmt. Enhancements +
- Enhance Cyber Reporting –

Protect

- ODN Security Improvement
- Gas SCADA Network Protection
- Customer Information Protection
- Smart Grid Security
- Application Integration for Access Mgmt.
- Patch Automation +
- Automate Cloud Security +
- Catalog Privileged Accounts & Access
- Network Access Control –

Detect

- Enterprise User & Behavior Analytics
- Identity Analytics
- Security Analytics & Adv. Monitoring –
- Security Monitoring Capacity Extension +
- Security Monitoring Lifecycle +

Respond

- Optimize Cyber Response
- Enhance Cybersecurity Labs & Forensics +/-
- Cyber Response Automation

**Aligns with NIST Cybersecurity Framework*

Financials

Mitigation		Pre RAMP (2017-2019)	Proposed (2020-2022)	Alternative 1	Alternative 2
1	Identify	$ 19,079	$ 11,363	$ 12,363	$ 11,033
2	Protect	$ 52,121	$ 57,878	$ 67,378	$ 51,818
3	Detect	$ 17,330	$ 20,487	$ 24,542	$ 14,897
4	Respond	$ 4,205	$ 10,654	$ 11,706	$ 9,755
Total		**$ 92,735**	**$ 100,383**	**$ 115,989**	**$ 87,504**

**Costs are high-level estimates*

***Represents all dollars (including GT&S and TO)*

"We have to keep building our security walls higher and higher, because these cyber criminals are building longer and longer ladders."

- Dame Dido Harding, CEO of Talk Talk

Lessons Learned and Next Steps

- The analysis required for RAMP reaffirmed our current understanding of risk drivers and consequences.
- We will continue to use a risk-informed approach aligned with the NIST Cybersecurity Framework to protect the Utility against cyber attack.
- We will continue to engage with our peers and the industry to improve our quantitative methods.
- The threat is evolving; continued effort will be required to mitigate the risk of cyber attacks by active adversaries.

Thank You