PG&E 2020 Risk Assessment and Mitigation Phase Post-Filing Workshop, Part 1

RAMP Overview & Risk Modeling

July 14, 2020

SAFETY MOMENT

Agenda

1. RAMP OVERVIEW
2. RISK SELECTION
3. MAVF IMPLEMENTATION
4. RISK ANALYSIS
5. RISK SPEND EFFICIENCY
6. CROSS-CUTTING FACTORS
7. WORKPAPERS OVERVIEW
8. WORKSHOP, PART 2 AGENDA

1. RAMP OVERVIEW

PG&E's 2020 RAMP Journey

Nov 2017

PG&E's 2017 RAMP Report Filed

Mar 2018

SED RAMP Report Issued

Dec 2018

S-MAP Settlement Agreement D.18-12-014 (S-MAP Settlement) Adopted

Nov 2019

Workshop #1: 2020 RAMP Implementation Overview

Jan 2020

- Workshop #2: Modeling Approaches.
- Rate Case Plan Decision D.20-01-002 issued. RAMP report date moved up to June 30th from Nov 30th, 2020

Feb 2020

Workshop #3: Preliminary RAMP Risks List

Jun 2020

PG&E's 2020 RAMP Report Filed

RAMP Summary

Data Driven Approach	• More extensive use of data compared to 2017. • Emphasis on PG&E-specific data.
Event-Based Risk Register	• Consolidated ~200 individual risks to 35 current corporate risks. • Consistent definition focused on Risk Events. • Cross-Cutting Factors.
Implementation of S-MAP Settlement Risk Framework	• Implemented MAVF, incorporated tranches, and calculated risk spend efficiency (RSE) as per the Settlement. • New Python-based tools.

PG&E's 2020 RAMP Report Structure

Chapter	Title	
1	Introduction	Foundational Information
2	PG&E's Enterprise Risk Management Framework	
3	Risk Modeling and Risk Spend Efficiency	
4	Risk Selection	
5	Safety Culture and Compensation	
6	Pandemic Impact Assessment	
7	Loss of Containment (LOC) on Gas Transmission Pipeline	RAMP Risk Chapters
8	LOC on Gas Distribution Main or Service	
9	Large Overpressure Event Downstream of Gas Measurement and Control Facility	
10	Wildfire	
11	Failure of Electric Distribution Overhead Assets	
12	Failure of Electric Distribution Network Assets	
13	Large Uncontrolled Water Release	
14	Real Estate and Facilities Failure	
15	Third Party Safety Incident	
16	Employee Safety Incident	
17	Contractor Safety Incident	
18	Motor Vehicle Safety Incident	
19	Other Safety Risks	Foundational Information
20	Introduction to the Cross-Cutting Factors	Cross-Cutting Factors Analysis
Attachment A	Cross-Cutting Factors	
21	Steady-State Operations	2020 GRC Settlement Agreement
Appendix A	RAMP Acronym List	

RAMP Risk Chapter Structure

Each RAMP Risk Chapter consists of the following sections.

A

Executive Summary

Risk Overview and Definition

B

Risk Assessment

Background, Bow Tie, Risk Exposure, Tranches, Drivers, Cross-Cutting Factors, Consequences

C

Controls and Mitigations

2017-2019 Controls and Mitigations Update

D

2020-2022 Mitigation Plan

Planned Mitigations and Controls

E

2023-2026 Proposed Plan

Proposed Mitigations and Controls, Forecast Costs and RSE Analysis for Proposed Mitigations

F

Alternative Analysis

List of Mitigation Alternatives, Forecast and RSE Analysis for Alternatives and Alternative Mitigation Plan(s)

2. RISK SELECTION

RAMP Risk Selection Process

Consistent with the S-MAP Settlement Agreement, Item No. 9:

> *…the utility will sort its ERR (Enterprise Risk Register) risks in descending order by the Safety Risk Score. For the top 40% of ERR risks with a Safety Risk Score greater than zero, the utility will compute a Multi-Attribute Risk Score using at least the Safety, Reliability and Financial Attributes…*

Settlement Step 1B
- Start with Risks on Enterprise Risk Register

→

Settlement Step 2A
- Identify all Safety Risks
- Compute MARS for top 40% of Safety Risks

→

Settlement Step 2B
- Utility selects Preliminary risks based on the top 40%
- Utility hosts workshop to gather input
- Utility selects the final list based on input received from workshop

PG&E Selection Criteria

1. Determine ERR risks with a non-zero Safety Risk Score
2. Determine top 40% on non-zero safety risks, rounding up
3. For any risk not selected in step 2, if a risk's Safety Risk Score is within 20% of the Safety Risk Score of the lowest scored risk in step 2, add it to the list

RAMP Risk Selection Process, continued

Changes since Workshop #3:

- Updated Risk Scores to reflect 2023 Test Year Baseline.
- Incorporated 2019 data.
- Incorporated feedback on Tranches.
- Incorporated cross-cutting factors.

Revisions above did not result in changes to the list of RAMP Risks.

		2023 RAMP Score		Preliminary Score		
Rank	Risk Event	Safety Risk Score	Multi-Attribute Risk Score	Safety Risk Score	Multi-Attribute Risk Score	Preliminary Rank
1	Wildfire	9,865	24,343	8,403	20,041	1
2	Third Party Safety Incident	887	944	1,592	1,642	2
3	Loss of Containment on Gas Transmission Pipeline	128	289	23	49	9
4	Contractor Safety Incident	94	94	116	116	5
5	Employee Safety Incident	86	90	120	124	4
6	Loss of Containment on Gas Distribution Main or Service*	72	99	86	108	7
7	Real Estate and Facilities Failure	69	97	104	142	6
8	Large Uncontrolled Water Release (Dam Failure)	41	70	42	71	8
9	Failure of Electric Distribution Overhead Assets	18	526	8	453	11
10	Motor Vehicle Safety Incident	16	17	217	218	3
11	Failure of Electric Distribution Network Assets	6	7	12	12	10
12	Large Overpressure Event Downstream of Gas M&C Facility	5	13	7	8	12

* Combined to include the LOC Gas Distribution Pipeline – Non-Cross Bore and LOC Gas Distribution Pipeline – Cross Bore risks from the Jan 21, 2020 Enterprise Risk Register.

3. MAVF IMPLEMENTATION

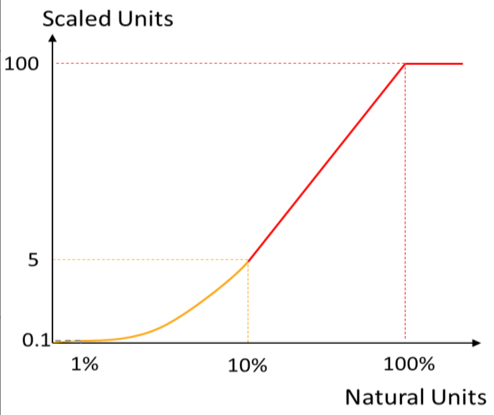
PG&E's Multi-Attribute Value Function (MAVF)

MAVF is used to combine different consequence attributes to a unit-less consequence of risk event (CoRE) value.

MAVF

Attributes		Range	Natural Units	Weight
Safety	4.9	0 - 100	Equivalent Fatalities[2]	50%
Electric Reliability	500M	0 - 4 Billion	Customer Minutes Interrupted (CMI)	20%
Gas Reliability	-	0 - 750,000	Customers Affected	5%
Financial[1]	800M	0 - $5B	Dollars ($)	25%

Scaling Function



CoRE

4,982

Multi-Attribute Risk Score
=
Exposure x LoRE x **CoRE**

[1] Pursuant to D.18-12-014 and D.16-08-018, shareholders' financial interests are excluded.
[2] Equivalent Fatalities = 1 for fatality and 0.25 for series injuries. Where serious Injury is an injury that require in-patient hospitalization of an individual.

MAVF Scaling Function Aligns to PG&E's Risk Management Objective

S-MAP Settlement MAVF Principle 5 – Scaled Units

Construct a scale that converts the range of natural units (from Row 3) to scaled units to specify the relative value of changes within the range, including **capturing aversion to extreme outcomes** or indifference over a range of outcomes.

The scaling function can be linear or non-linear. For example, the scale is linear if the value of avoiding a given change in Attribute level does not depend on the Attribute level. Alternatively, **the scale is non-linear if the value of avoiding a given change in Attribute level differs by the Attribute level.**

PG&E's Risk Management Approach

PG&E's MAVF aligns with PG&E's focus on mitigating catastrophic, tail events.

Consequences of catastrophic events are hard to determine, and can be underestimated.	Tend to be concentrated and disproportionately affects communities.	Have the potential to overwhelm emergency facilities and infrastructure.	Have unforeseen consequences that are not factored into operations and contingency planning.

- Extreme events threaten the sustainability of both the organization and the community it serves.
- Tail risks are sometimes so difficult to perceive that they seem impossible, but we know that this is not the case.
- Managing expected value can result in overlooking or ignoring highly unlikely tail risks.
- EORM needs to provide a tool to clarify tail risks to improve decision making in order to reduce the likelihood of ignoring tail risks.

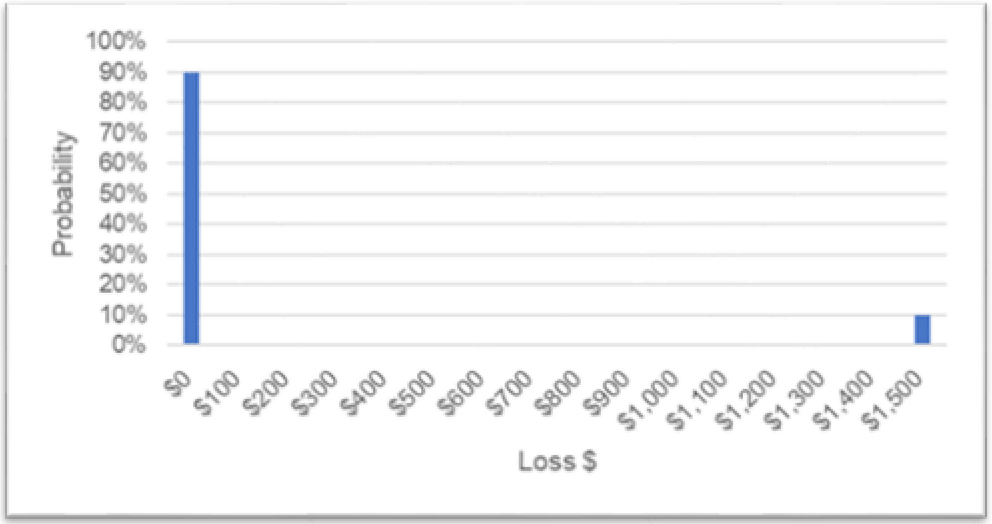
PG&E's Risk Management Objective (continued)

PG&E's Risk Management Objective is to Mitigate Catastrophic Tail Events …

Low Consequence/High Likelihood Risk Event

Mean = $150

High Consequence/Low Likelihood Risk Event

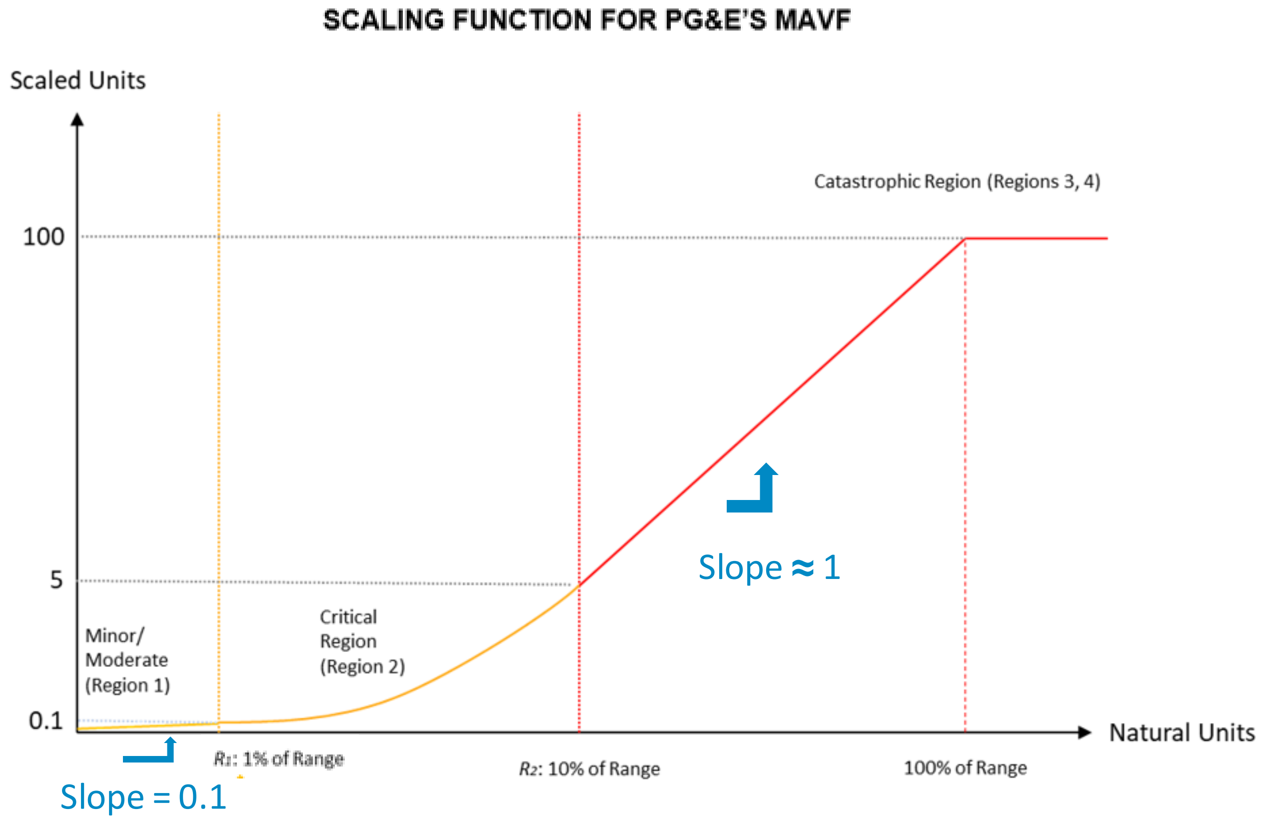


Mean = $150

- A linear scaling function manages to averages and will not distinguish between the two sets of consequences.
- PG&E's non-linear scaling function highlights tail risk.

PG&E's MAVF Scaling Function

PG&E's Scaling Function gives 10 times more weight to the catastrophic region to reflect aversion to extreme outcomes in risk scores and risk reduction scores.



0 to 1% of the Range Linear function from 0 to 0.1 Scaled Units	**1 to 10% of the Range** Quadratic function from 0.1 to 5 Scaled Units	**10 to 100% of the Range** Linear function from 5 to 100 Scaled Units. Capped at 100 Scaled Units.[1]

[1] S-MAP Settlement defines scaled units as "a value that varies from 0 to 100. (…). The scaled unit is set to 100 for the least desirable level of natural unit in the range of natural units.

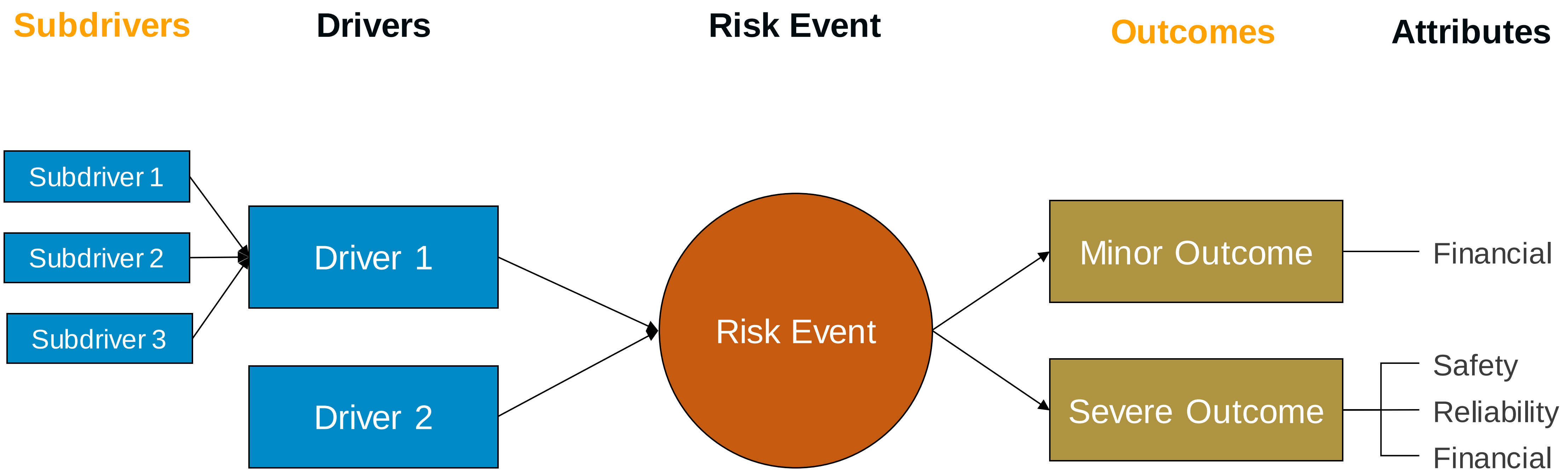
4. RISK ANALYSIS

Bow Tie Illustration

The Bow Tie illustration gives a visual summary of the Drivers and Consequences of a Risk Event.

PG&E adds two additional elements to the Bow Tie: Subdrivers and Outcomes.

Illustrative Risk Bowtie



Bow Tie Elements – Drivers and Outcomes

DRIVERS

Drivers are direct causes of the risk event, and determine the likelihood or frequency of a risk event

- An exhaustive list of things which could cause the risk event
- Can be decomposed into sub-drivers
  - For example, failure of a fuse is a sub-driver to the Equipment Failure driver
- Can lead to different outcomes – one driver may be more likely to lead to a severe outcome than others
  - For example, on a Gas Transmission Pipeline the Third Party Damage driver is more likely to lead to a rupture than the Corrosion driver which is more likely to cause a leak.

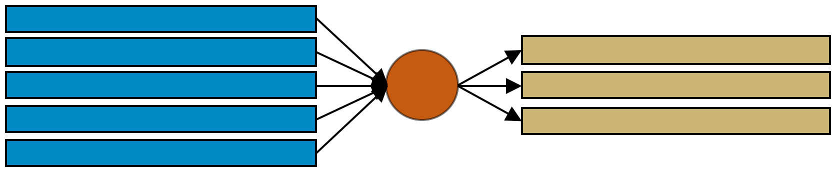
OUTCOMES

Outcomes characterize the severity of a risk event, and determine the consequence of a risk event

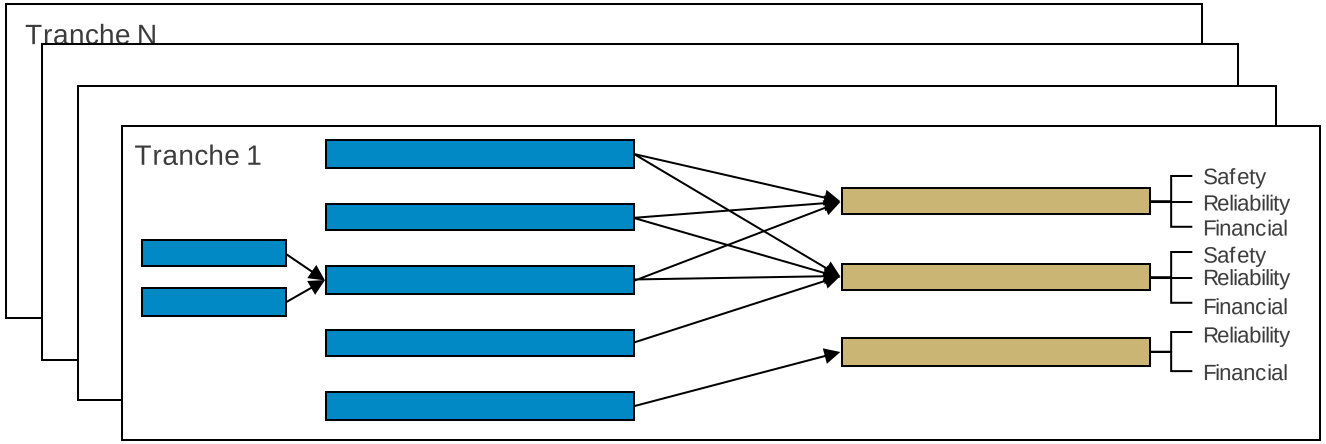
- Risk event may play out in different ways, and outcomes differentiate the various risk event manifestations
- Having multiple outcomes allows us to differentiate low and high consequence risk events instead of having an "average" risk event
  - For example, a loss of containment event with ignition is a severe outcome whereas a leak without ignition is a minor outcome
- Conditional distributions can be used for consequences - the distributions are different based on the outcome.

Bow Tie Elements - Tranches

Bow-tie presentation…



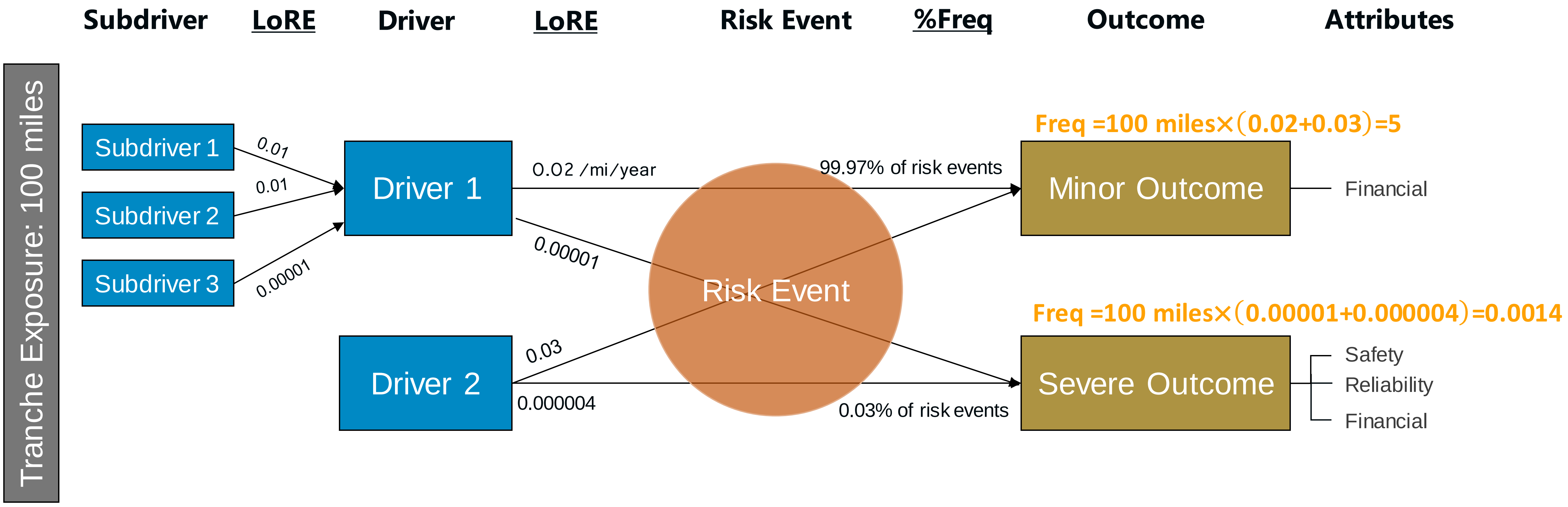
…under the hood, there are as many bow-ties as tranches



Bow Tie Elements – Frequency Calculation

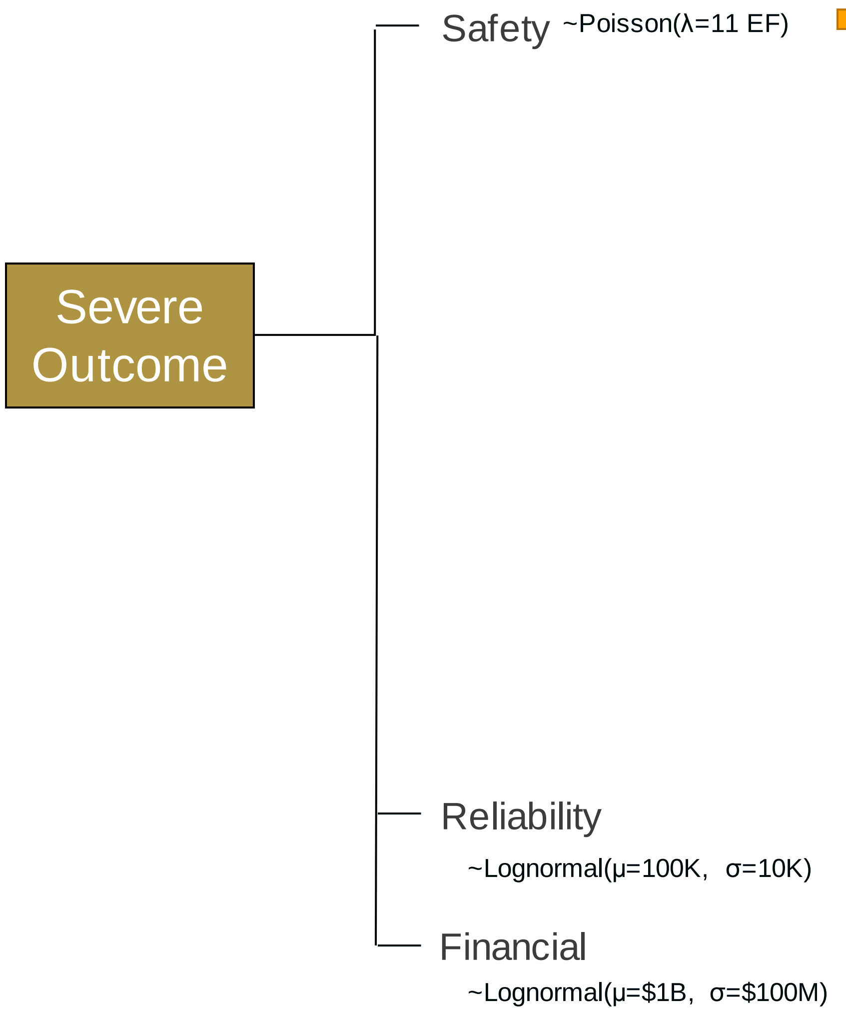
Frequency = Exposure x LoRE

It is calculated at the tranche, driver, subdriver and outcome level.



Risk Score Calculation Example: Severe Outcome CoRE

Monte Carlo Simulation is used to calculate CoRE for each Attribute/Outcome/Tranche.



Safety

Trial	Sim. Natural Unit (EF)	Scaled	Trial CoRE
1	12	7.1	3,556
2	14	9.2	4,611
3	8	3.2	1,611
4	5	1.3	646
5	12	7.1	3,556
6	8	3.2	1,611
7	10	5.0	2,503
8	14	9.2	4,611
9	13	8.2	4,083
10	15	10.3	5,139
		Safety CoRE	3,193
	...	...	...
		Reliability CoRE	**409**
	...	...	...
		Financial CoRE	**3,931**

<u>Calculation Steps</u>

1. Simulate Natural Unit trials from the Conditional Consequence Distributions
2. Using the Simulated Natural Unit, compute the scaled unit using the MAVF. Using Trial #1:

$$\frac{100-5}{1.0-0.1}\left(\frac{12\,EF}{100\,EF}-0.1\right)+5=7.1$$

3. Compute the Trial CoRE using the scaler (1000), Attribute Weight (50% for Safety), and Scaled Unit value

$$1{,}000\times 50\%\times 7.1=3{,}556$$

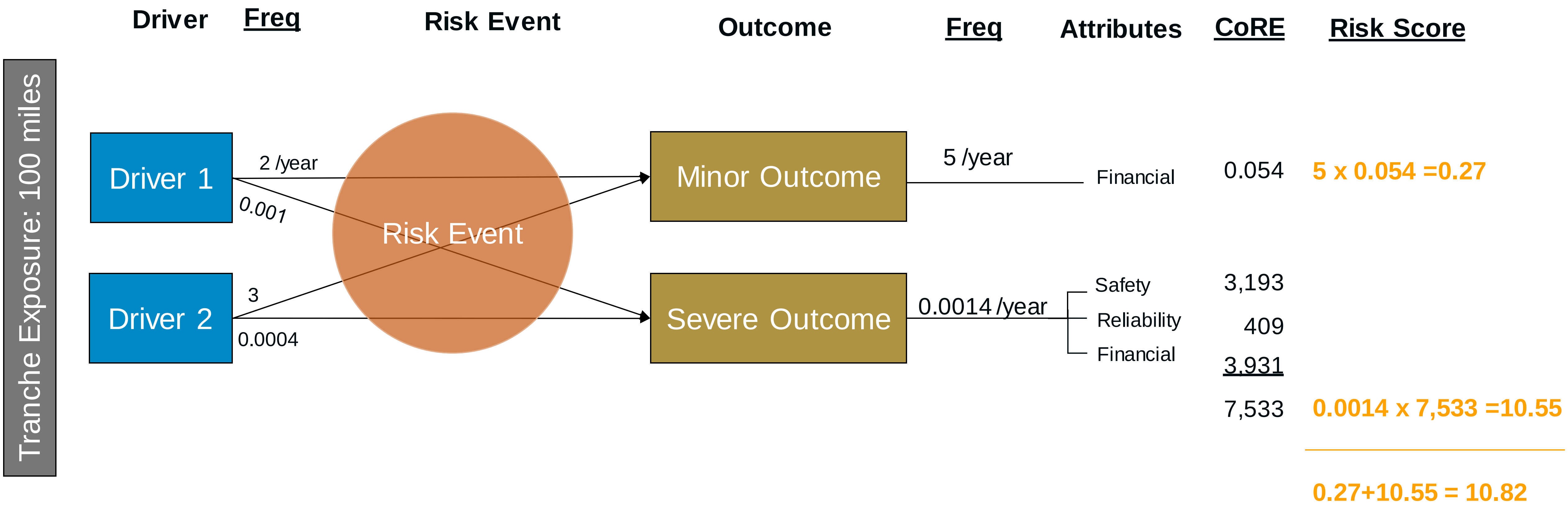
4. Compute Attribute CoRE by taking the average over each Trial CoRE

$$31{,}926/10=3{,}193$$

5. Repeat process for Gas Reliability and Financial attributes

Bow Tie Elements – CoRE and Risk Score Calculation

Risk Score = Frequency x CoRE



5. RISK SPEND EFFICIENCY

Discounting and Long-Term Benefits

RSE is [NPV of Risk Reduction Scores] divided by [NPV of Program Costs]

Per Row 25 of the S-MAP Settlement Agreement, the RSE *"should reflect the full set of benefits"* and use present values.

$$RSE = \frac{\text{NPV(Pre-mitigation Risk Scores)} - \text{NPV(post-mitigation Risk Scores)}}{\text{NPV(Program Costs)}}$$

- PG&E's *After-Tax Weighted Average Cost of Capital* (7.1% per annum) is used for all discounting.
- Program costs include capital and expense.
- Revenue Requirements are not currently included as part of capital program costs.

RSE Calculation Example: Mitigation Effectiveness

Mitigation Effectiveness is used to calculate post-mitigation Risk Score.

Mitigation Program

Targets Safety Consequences of Severe Outcome
Effectiveness: 10%
Scope: 100 miles/year for 4 years
Benefit duration: 1 year only
Cost: $500,000/year

Natural Unit decreased by 10%

Safety

Trial	Pre-Mitigation Natural Unit (EF)	Post-Mitigation Natural Unit (EF)	Scaled	Trial CoRE
1	12	10.8	5.8	2,922
2	14	12.6	7.7	3,872
3	8	7.2	2.6	1,310
4	5	4.5	1.1	528
5	12	10.8	5.8	2,922
6	8	7.2	2.6	1,310
7	10	9.0	4.1	2,032
8	14	12.6	7.7	3,872
9	13	11.7	6.8	3,397
10	15	13.5	8.7	4,347
			Safety CoRE	2,651

Calculation Steps

1. Compute mitigated Safety CoRE using post-mitigation Natural Unit trial values = **2,651**

2. Compute post-mitigation Severe Outcome CoRE

$$2,651 + 409 + 3,931 = 6,991$$

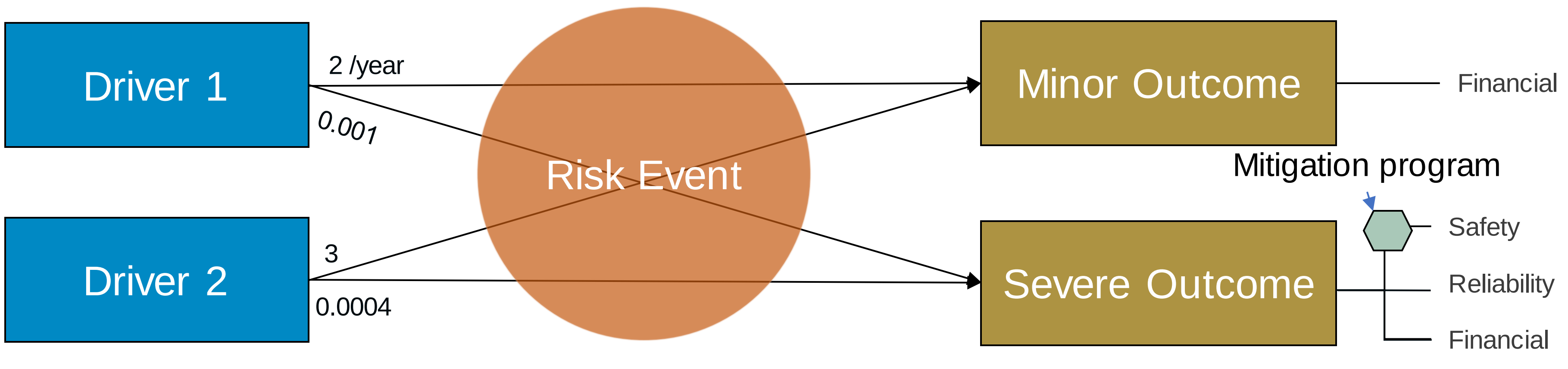
3. Compute post-mitigation Risk Score

$$= (5 \times 0.054) + (0.0014 \times 6,991)$$
$$= 0.27 + 9.78$$
$$= 10.05$$

RSE Calculation Example (continued)

Mitigation Program
Targets **Safety** Consequences of Severe Outcome
Effectiveness: 10%
Scope: 100 miles/year
Benefit duration: 1 year only
Cost: $500,000/year

Driver	Risk Event	Outcome	Attributes	CoRE	Risk Score



Attribute	CoRE	Risk Score
Minor Outcome – Financial	0.054	5x 0.054 = 0.27
Severe Outcome – Safety	2,651	
Severe Outcome – Reliability	409	
Severe Outcome – Financial	3,931	
	6,991	0.0014 x 6,991 =9.79
		10.06

Risk Reduction = 10.82 – 10.06 = 0.76

$$RSE = \frac{0.76}{\$0.5M} = 1.52$$

Risk Reduction and Spend identical over 4 program years. RSE using 4-year NPV would be 2.79/1.81=1.54

Pre- and Post-Mitigation Risk Scores

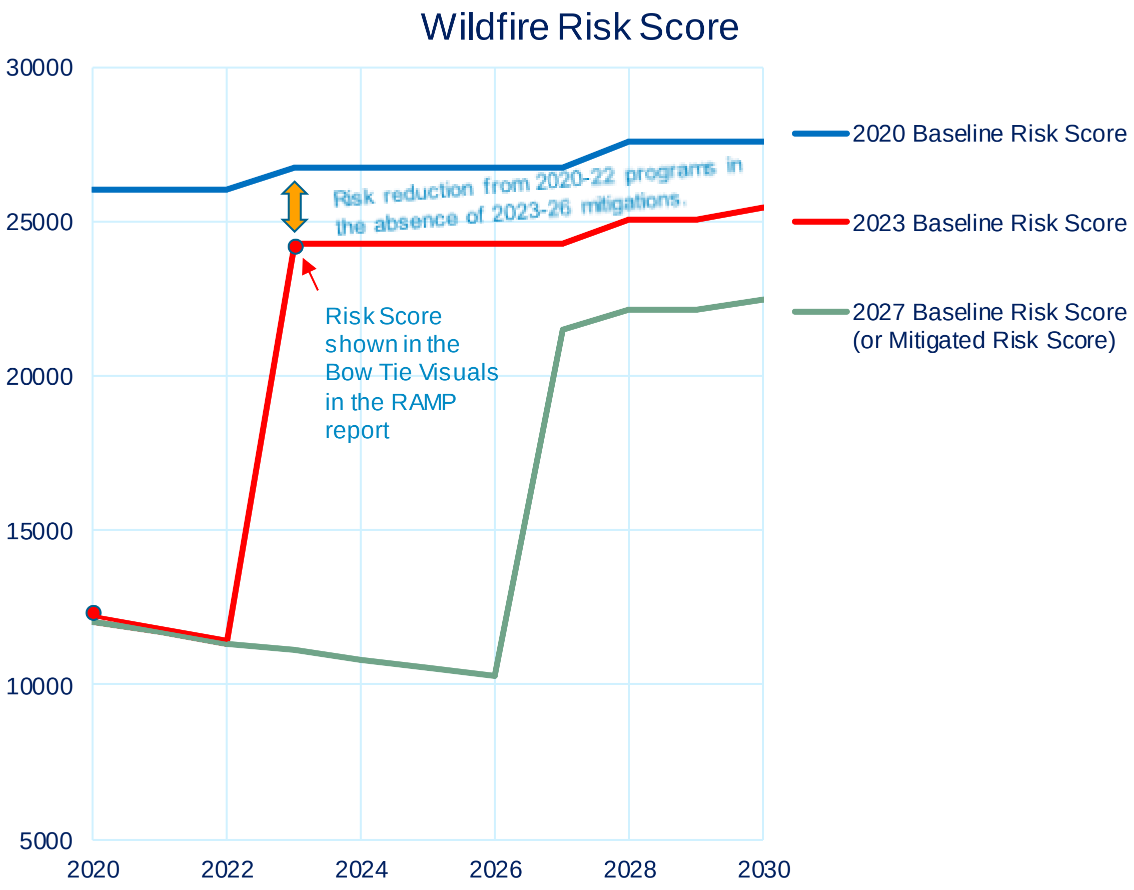
Test Year Baseline Risk Score: Accounts for benefits from any mitigations that are planned in the *current* GRC. Includes long-term benefits from 2020-22 programs.

	2020	2021	2022	2023	2024	2025	2026
	← Current GRC period		→	← Next GRC period			→
2020 Baseline Risk Score	600	600	690	690	740	780	830
Risk Reduction from 2020 Programs	(50)	(50)	(50)	(40)	(40)	(40)	(40)
Risk Reduction from 2021 Programs		(40)	(40)	(40)	(30)	(30)	(30)
Risk Reduction from 2022 Programs			(30)	(30)	(30)	(20)	(20)
Test Year Baseline Risk Score (Pre-Mitigation)	550	510	570	**580**	640	690	740
Risk Reduction from 2023 Programs				(60)	(60)	(50)	(50)
Risk Reduction from 2024 Programs					(60)	(60)	(50)
Risk Reduction from 2025 Programs						(60)	(60)
Risk Reduction from 2026 Programs							(50)
Post-Mitigation Risk Score	550	510	570	520	520	520	530

Includes benefits from mitigations proposed in 2020 RAMP.

2020 vs 2023 Baseline Risk Scores

2020 Baseline Risk Scores are adjusted by the risk reduction benefits of any mitigations that are expected to be implemented prior to 2023, before doing analysis for the GRC period (2023 – 2026) under review.



*Baseline Year: The year to base the mitigations that are accounted for in the risk score.

2020 Baseline Risk Scores

- Accounts for risk reduction from **pre-2020 mitigations**.
- 2020 baseline risk score shows the current risk because it does not account for risk reduction from mitigations that have not yet been implemented.

2023 Baseline Risk Scores (aka TY Baseline Score)

- Accounts for risk reduction from **pre-2023 mitigations**.
- Calculated using the 2020 baseline frequency and consequence of a risk event, adjusted by overall effectiveness of mitigations implemented from 2020 through 2022.
- Used to evaluate mitigations planned for 2023 and later.
- S-MAP Settlement:

  "If data reflecting past results are used, that data must be supplemented by SME judgement that takes into account the benefits of any mitigations that are expected to be implemented prior to the GRC period under review in the RAMP submission."

Pre-2023 Mitigations Accounted for in the 2023 Baseline Score for Wildfire Risk:

M1-Enhanced Vegetation Management, M2-System Hardening, M3-Non-Exempt Surge Arrester Replacement M11-Remote Grid (2020 - 2022), RIM Mitigation (2020 - 2022), EOC Enhancements (2020 - 2022), Mutual Aid Enhancements (2020 - 2022)

Risk Reduction of a Mitigation in a Portfolio

Risk reduction from an individual mitigation also depends on which other mitigations are included in the proposed portfolio of work.

Example:

1. Enhanced Vegetation Management (EVM) reduces the likelihood of the vegetation driver for all outcomes.
2. Public Safety Power Shutoff (PSPS) reduces the likelihood of the equipment failure and vegetation drivers for Red Flag Warning outcomes.
3. Both EVM and PSPS address the vegetation driver of Red Flag Warning outcomes in the same tranche.

The risk reduction achieved by EVM is lower in the presence of PSPS than it would be as a stand-alone mitigation.

- Risk reduction from a set of mitigations is lower than the sum of risk reductions from individual mitigations in the absence of other mitigations, if those mitigations that target the same tranche, sub-driver and/or outcome.
- In order to not overestimate risk reduction when there are overlapping mitigations, we calculate overall risk reduction from a portfolio of mitigations and then allocate it to individual mitigations based on their marginal risk reduction.
- The risk reduction from each mitigation, thus the RSE of each mitigation, depends on the portfolio of planned mitigations.
- Where there is no overlap among mitigations (in applicable tranche, sub-driver and/or outcome combinations) it is unnecessary to allocate risk reduction.

Illustrative Example: Portfolio Impact / Risk Reduction Allocation

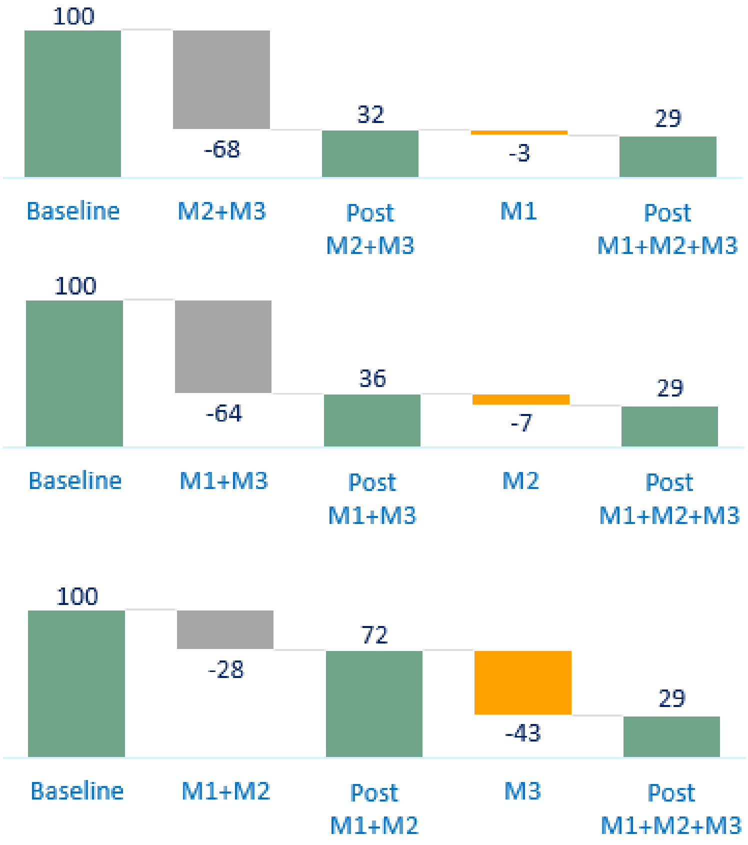
In the Absence of Other Mitigations

The incremental risk reduction from each mitigation in the absence of the other mitigations is 10, 20 and 60 for M1, M2 and M3 respectively.

Incremental Risk Reduction

In the Presence of Other Mitigations

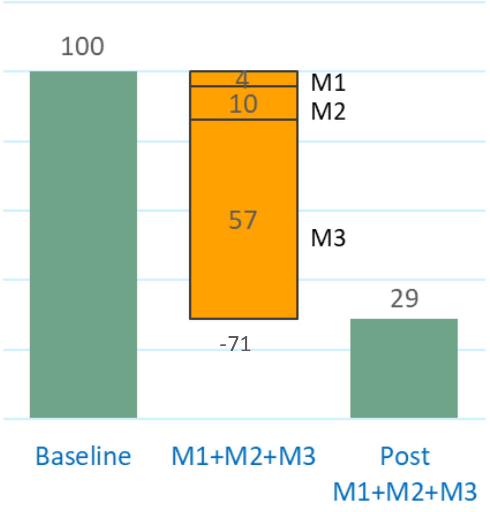
However, portfolio of mitigations, M1, M2, M3 does not achieve a total risk reduction of 10 + 20 + 60 = 90. The overall risk reduction from the portfolio is 100 – 29 = 71.
Therefore, we need to allocate overall risk reduction to individual mitigations to estimate the RSE of the individual mitigation.



Marginal Risk Reduction

We allocate overall risk reduction in proportion to the Marginal Risk Reduction: 6%, 13% and 81% of 71 for M1, M2 and M3 respectively.

Allocated Risk Reduction



Overall Risk Reduction = 100 - 29 = 71

Treatment of Programs

PG&E has three different kinds of programs that reduce risk and they are treated differently for the purposes of calculating an RSE.

Program Type	Definition	Treatment	Reason
Mitigation	Measure or activity proposed or in process designed to reduce the impact/consequences and/or likelihood/probability of an event (S-MAP Lexicon).	RSEs are calculated for each mitigation.	
Control	Currently established measure that is modifying risk (S-MAP Lexicon).	RSEs are calculated for two pilot controls.	Part of existing operations; difficult to estimate counterfactual Risk Scores. PG&E piloted RSE calculations for two controls in RAMP and will calculate more RSEs for controls in the GRC.
Foundational Program	A program or activity that does not have a stand-alone risk-mitigation effect, but is required to enable multiple mitigations.	An RSE is not calculated (RSE=0)	Foundational programs represent work that facilitates the implementation of multiple mitigations, hence risk-mitigation effects cannot be directly attributed to the foundational programs themselves. (e.g. collaborative research on utility ignition data, computing resources).

6. CROSS-CUTTING FACTORS

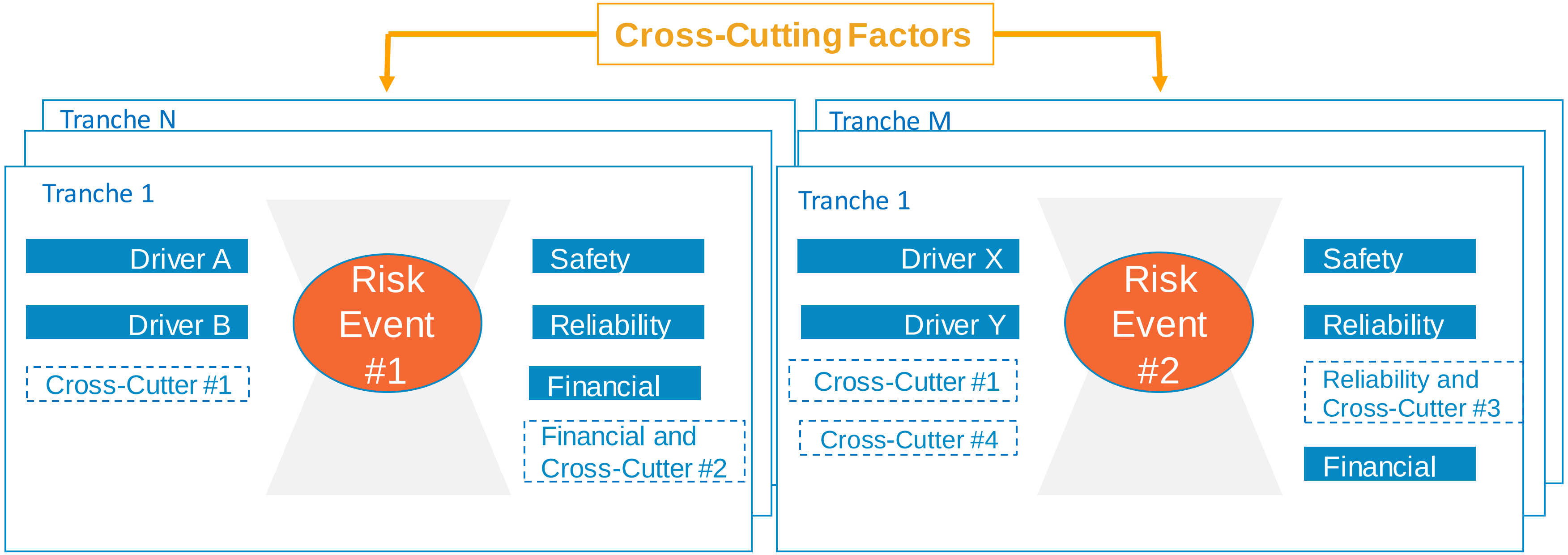
Approach for Cross-Cutting Factors in 2020 RAMP

Cross-Cutting factors are not risks in and of themselves, but impact other risks

- Some Cross-Cutting factors will not appear on the Bow Tie because they do not make a separate contribution to the frequency or the outcome of the risk event

Programs that address these Cross-Cutting factors typically apply to multiple risks, drivers, tranches, and outcomes.

- Only one RSE is calculated per Cross-Cutting factor (as opposed to per program) due to the large number of potential combinations of risks, drivers, tranches, and outcomes



Impact of Cross-Cutting Factors

A cross-cutting factor can be a unique risk driver or a component of an existing driver, therefore impacting the **likelihood** of an event.

A cross-cutting factor also impacts the **consequence** of an event, increasing the impact of potential outcomes.

No.	Cross-Cutting Factor	Impacts the Likelihood of a Risk Event	Impacts the Consequence of a Risk Event
1	Climate Change	x	x
2	Cyber Attack	x	x
3	Emergency Preparedness and Response (EP&R)		x
4	Information Technology (IT) Asset Failure	x	x
5	Physical Attack	x	
6	Records and Information Management (RIM)	x	x
7	Seismic	x	x
8	Skilled and Qualified Workforce (SQWF)	x	

Modeling Cross-Cutting Factors

Cross-cutting factors were modeled in many different ways.

1. Driver

Extracted from Existing:
Based on historical data
e.g. Physical Attack/Employee Safety

Added Frequency:
Frequencies estimated by other methods when historical data is unavailable
e.g. Seismic/Failure of Electric Distribution Network Asset

2. Consequence Multiplier

Reflects the amplification effect the cross-cutting factor has on a Consequence Attribute

e.g. RIM/LOC Gas Transmission Pipeline.

3. Outcome

The cross-cutting factor is not a driver, but leads to different consequences when it coincides with the Risk Event

e.g. Cyber Attack/Large Over-pressurization Event.

4. Unique Driver/Outcome Combination

The cross-cutting factor is a driver that leads to distinct outcomes

e.g. Seismic/Failure of Distribution Overhead Asset

5. Escalating Frequency

Escalates the frequency of existing drivers over time

e.g. Climate Change/Wildfire

6. Embedded

The impact of the cross-cutting factor is already accounted for in the frequency and consequence

e.g. EP&R/Wildfire

Example: Cross-Cutting Factors in Failure of Distribution Overhead Assets Risk

Drivers

Driver	Freq	% Freq	% Risk
D-Line Equipment Failure	8663	35%	30%
Other	7348	30%	26%
Vegetation	5279	21%	20%
Animal	1999	8%	7%
Natural Hazard	1188	5%	4%
Other PG&E Assets or Processes	149	0.6%	0%
Human Performance	119	0.5%	0.4%
CC - Seismic Scenario	41	0.2%	12.4%
CC - Physical Attack	27	0.1%	0.1%
CC - SQWF	15	0.1%	0.1%
CC - RIM	6	0.0%	0.0%
Aggregated	24834 | Events / Yr		

Exposure

80716

miles

Failure of Distribution Overhead Assets

Risk Score

526

Outcomes

Outcome	CoRE	%Freq	%Risk
Asset Failure / Not associated with Ignition / Not coincided with IT Asset Failure	0.02	98.0%	87%
Asset Failure / Associated with Ignition	-	1.8%	-
Asset Failure / Seismic scenario	1.60	0.2%	12%
Asset Failure / Not associated with Ignition / Coincided with IT Asset Failure	0.12	0.1%	0.3%
Aggregated	0.02	100%	100%

Escalating Frequency

Driver – Added Frequency

Driver – Extracted from Existing

Unique Driver/ Outcome Combo

Embedded: EP&R

Consequence Multiplier: RIM

Outcome

Lessons Learned

We have made a lot of progress in this RAMP report, but we also recognize a lot of areas to improve upon.

Data Quality

The RAMP analysis highlights the importance of effective data management and governance. A framework for dealing with insufficient and/or low-quality data is needed.

Modeling

Having a broader set of distributions will allow us to integrate asset-level information into the models.

Lack of data creates challenges for modeling tail events.

Cross-Cutting Factors

Lack of data and added complexity contributed to difficulty in explicitly representing the effect of cross-cutting factors.

Risk Spend Efficiency

RSEs are an important, but not an exclusive reason for undertaking mitigations.

Challenges translating planning units to modeling units introduce additional uncertainty to RSE.

IT Asset Failure

More works need to be done to capture the effects of IT asset health.

Granularity of Tranches

PG&E's evaluation of tranches is ongoing.

Additional data will lead to more refined tranches.

7. MODELING WORKPAPERS

Modeling Workpaper Package

PG&E will file modeling workpapers on July 17.

Modeling Workpaper Package will include the following items:

1. Modeling Input Files
2. Bowtie Output Files
3. Source Documentation
4. User Guide

Let’s do a walk-through of a modeling Input file and bowtie output file.

8. WORKSHOP, PART 2 AGENDA

Appendix

S-MAP SA: Step 1A – Building a MAVF

No.	Element Name	Element Description and Requirements
1.	MAVF	A utility's MAVF should be constructed by following these six principles (see Rows 2-7, below). The MAVF is required to be built once but the utility may adjust its MAVF over time. Any changes to the MAVF must adhere to the principles of construction set forth in Rows 2 through 7 below.
2.	MAVF Principle 1 – Attribute Hierarchy	Attributes are combined in a hierarchy, such that the top-level Attributes are typically labels or categories and the lower-level Attributes are observable and measurable.
3.	MAVF Principle 2 – Measured Observations	Each lower-level Attribute has its own range (minimum and maximum) expressed in natural units that are observable during ordinary operations and as a consequence of the occurrence of a risk event.
4.	MAVF Principle 3 – Comparison	Use a measurable proxy for an Attribute that is logically necessary but not directly measurable. This principle only applies when a necessary Attribute is not directly measurable. For example, a measure of the number of complaints about service received can be used as a proxy for customer satisfaction.
5.	MAVF Principle 4 – Risk Assessment	When Attribute levels that result from the occurrence of a risk event are uncertain, assess the uncertainty in the Attribute levels by using expected value or percentiles, or by specifying well-defined probability distributions, from which expected values and tail values can be determined. Monte Carlo simulations or other similar simulations (including calibrated subject expertise modeling), among other tools, may be used to satisfy this principle.
6.	MAVF Principle 5 – Scaled Units	Construct a scale that converts the range of natural units (from Row 3) to scaled units to specify the relative value of changes within the range, including capturing aversion to extreme outcomes or indifference over a range of outcomes. The scaling function can be linear or non-linear. For example, the scale is linear if the value of avoiding a given change in Attribute level does not depend on the Attribute level. Alternatively, the scale is non-linear if the value of avoiding a given change in Attribute level differs by the Attribute level.
7.	MAVF Principle 6 – Relative Importance	Each Attribute in the MAVF should be assigned a weight reflecting its relative importance to other Attributes identified in the MAVF. Weights are assigned based on the relative value of moving each Attribute from its least desirable to its most desirable level, considering the entire range of the Attribute. One means of incorporating a weighting process was presented in the February 17, 2017 Report of Joint Intervenor Test Drive Step 1 Results, "Specifying the Multi-Attribute Value Function," by Drs. Feinstein and Lesser. Weights are assigned based on actual Attribute measurement ranges, not a fixed weight arbitrarily assigned to an Attribute. For example, the Attribute weights will reflect the relative importance of moving the safety outcomes from the least to the most desirable levels as compared with moving financial outcomes from the least to the most desirable levels in a risky situation.

MAVF Attributes

- **Hierarchy:** Each Attribute consists of one lower-level Attribute of the same name (Principle 1) and is Measurable (Principle 2; Measured Observations). Proxies were not used (Principle 3 Comparison).
- **Environmental:** Accounted for financially (i.e., as part of the Financial consequences) because there aren't commonly accepted measures of non-monetary environmental consequences.
- **Levels:** Represented by probability distributions (e.g. $ consequence of a risk event). PG&E uses Monte-Carlo simulations of Attribute Levels based on these probability distributions (Principle 4 Risk Assessment).

MAVF Attribute Ranges and Natural Units

Ranges are defined on a per-event basis. Pursuant to D.18-12-014, S-MAP Settlement Agreement (SA) Revised Lexicon, "… *the largest observable value* (of an Attribute) *is the high end of the range*". PG&E interprets this to be based on historical and/or plausible worst-case scenarios.

- **Safety:** 0 to 100 EF. Based on loss of life due to recent events.
- **Electric Reliability:** 0 to 4 billion CMI. Based on Oct 26-29, 2019 PSPS event consequence of approximately 3.6 billion CMI.
- **Gas Reliability:** 0 to 750k customers affected. Based on scenario of an outage at a critical gas facility.
- **Financial:** 0 to $5 billion. Represents a financial loss commensurate with an Energy Crisis-type event. Per S-MAP SA, utility shareholders' financial interests are excluded and hence estimates from recent wildfires were not used.

S-MAP SA Step 3 – Mitigation Analysis

No.	Element Name	Element Description and Requirements
13.	Calculation of Risk	For purposes of the Step 3 analysis, pre- and post-mitigation risk will be calculated by multiplying the Likelihood of a Risk Event (LoRE) by the Consequences of a Risk Event (CoRE). The CoRE is the weighted sum of the scaled values of the levels of the individual Attributes using the utility's full MAVF.
14.	Definition of Risk Events and Tranches	Detailed pre- and post-mitigation analysis of mitigations will be performed for each risk selected for inclusion in the RAMP. The utility will endeavor to identify all asset groups or systems subject to the risk and each Risk Event associated with the risk. For example, if Steps 2A and 2B identify wildfires associated with utility facilities as a RAMP Risk Event, the utility will identify all drivers that could cause a wildfire and each group of assets or systems that could be associated with the wildfire risk, such as overhead wires and transformers. For each Risk Event, the utility will subdivide the group of assets or the system associated with the risk into Tranches. Risk reductions from mitigations and risk spend efficiencies will be determined at the Tranche level, which gives a more granular view of how mitigations will reduce risk. The determination of Tranches will be based on how the risks and assets are managed by each utility, data availability and model maturity, and strive to achieve as deep a level of granularity as reasonably possible. The rationale for the determination of Tranches, or for a utility's judgment that no Tranches are appropriate for a given Risk Event, will be presented in the utility's RAMP submission. For the purposes of the risk analysis, each element (i.e., asset or system) contained in the identified Tranche would be considered to have homogeneous risk profiles (i.e., considered to have the same LoRE and CoRE).
15.	Bow Tie	For each risk included in the RAMP, the utility will include a Bow Tie illustration. For each mitigation presented in the RAMP, the utility will identify which element(s) of its associated Bow Tie the mitigation addresses.
16.	Expressing Effects of a Mitigation	The effects of a mitigation on a Tranche will be expressed as a change to the Tranche-specific pre-mitigation values for LoRE and/or CoRE. The utility will provide the pre- and post-mitigation values for LoRE and CoRE determined in accordance with this Step 3 for all mitigations subject to this Step 3 analysis.
17.	Determination of Pre-Mitigation LoRE by Tranche	The pre-mitigation LoRE is the probability that a given Risk Event will occur with respect to a single element of a specified Tranche over a specified period of time (typically a year) in the planning period, before a future mitigation is in place.

S-MAP SA Step 3 – Mitigation Analysis (continued)

No.	Element Name	Element Description and Requirements
17.	Determination of Pre-Mitigation LoRE by Tranche	The pre-mitigation LoRE is the probability that a given Risk Event will occur with respect to a single element of a specified Tranche over a specified period of time (typically a year) in the planning period, before a future mitigation is in place.
18.	Determination of Pre-Mitigation CoRE	The pre-mitigation CoRE is the weighted sum of the scaled values of the pre-mitigation levels of the individual Attributes using the utility's full MAVF. The CoRE is calculated using the full MAVF tool constructed consistent with Step 1A above.
19.	Measurement of Pre-Mitigation Risk Score	The pre-mitigation risk score will be calculated as the product of the pre-mitigation LoRE and the pre-mitigation CoRE for each Tranche subject to the identified Risk Event.
20.	Determination of Post- Mitigation LoRE	The post-mitigation LoRE calculation will be conducted at the same level of granularity as the pre-mitigation risk analysis within Step 3. The calculated value is the probability of occurrence of a Risk Event after the future mitigation is in place.
21.	Determination of Post- Mitigation CoRE	The post-mitigation CoRE calculation will be conducted at the same level of granularity as the pre-mitigation risk analysis. The post-mitigation CoRE is the weighted sum of the scaled values of the post-mitigation levels of the individual Attributes using the utility's full MAVF.
22.	Measurement of Post-Mitigation Risk Score	The post-mitigation risk score will be calculated as the product of the post-mitigation LoRE and post-mitigation CoRE for each Tranche subject to the identified Risk Event.
23.	Measurement of Risk Reduction Provided by a Mitigation	The risk reduction provided by a risk mitigation will be measured as the difference between the values of the pre-mitigation risk score and the post-mitigation risk score.
24.	Use of Expected Value for CoRE; Supplemental Calculations	The utility will use expected value for the MAVF-based measurements and calculations of CoRE in Rows 13, 18, 19, 21, 22, and 23. If a utility chooses to present alternative calculations of pre- and post-mitigation CoRE using a computation in addition to the expected value of the MAVF, such as tail value, it does so without prejudice to the right of parties to the RAMP or GRC to challenge such alternative calculations.
25.	Risk Spend Efficiency (RSE) Calculation	RSE should be calculated by dividing the mitigation risk reduction benefit by the mitigation cost estimate. The values in the numerator and denominator should be present values to ensure the use of comparable measurements of benefits and costs. The risk reduction benefits should reflect the full set of benefits that are the results of the incurred costs. For capital programs, the costs in the denominator should include incremental expenses made necessary by the capital investment.

Risk Score Calculation

In PG&E's model, "LoRE x CoRE" is the Expected Risk of operating the system. The year *y* Risk per unit of exposure, $V_{t,y}$, is measured in Scaled Units and determined by the Likelihood, Consequence distributions and MAVF. In the example above,

Let *d* represent the different drivers/failure modes: $d \in \{d_1, d_2, \emptyset(\text{no event})\}$
Let $x_{t,y}$ represent the exposure (e.g. no. of miles in HFTD Tier 3) in the Tranche t

Risk $\text{Score}_{t,y}$ = Expected Tranche Risk for year *y* = $E\left[x_{t,y}V_{t,y}\right]$

$$= x_{t,y}\left(E\left[V_{t,y}|d=\emptyset\right].p_{t,y}(d=\emptyset) + E\left[V_{t,y}|\underbrace{d\in\{d_1,d_2\}}_{risk\,\text{event}}\right]\times p_{t,y}(d\in\{d_1,d_2\})\right)$$

$$= 0 + x_{t,y}\times\underbrace{E\left[V_{t,y}|d\in\{d_1,d_2\}\right]}_{\text{CoRE}}\times\underbrace{p_{t,y}(d\in\{d_1,d_2\})}_{\text{LoRE}} = \underbrace{E\left[V_{t,y}|d\in\{d_1,d_2\}\right]}_{\text{CoRE}}\times\underbrace{x_{t,y}\times\ p_{t,y}(d\in\{d_1,d_2\})}_{\text{Frequency}}$$

PG&E's model is consistent with Rows 13 & 24 of the SA.
Frequencies (i.e., incident counts) are used because they are observable or estimable.

The Bowtie Risk Score for year *y* is the sum of the individual Tranche Risk Scores:

$$Risk\ Score_y = E\left[V_y\right] = \sum_t E\left[x_{t,y}V_{t,y}\right] = \sum_t \text{CoRE}_{t,y}\times\text{Frequency}_{t,y}$$

Multi-Attribute Risk Score and Safety Risk Score

Consistent with the S-MAP SA, the risk scores are the product of the Likelihood of a Risk Event (LoRE), and the Consequence of a Risk Event (CoRE), LoRE x CoRE, per unit of Exposure, i.e.,

Multi-Attribute Risk Score (MARS) *= Exposure x LoRE x CoRE = Frequency x CoRE*

where

- Frequency is the product of the Exposure and LoRE.
- CoRE is the weighted sum of Scaled Units of four Attributes, multiplied by 1,000.
- The Scaled Unit of each Attribute varies from 0 to 100, consistent with its definition in the S-MAP SA and is the output of applying the MAVF’s Range and Scaling Function to the Attribute Levels.

Safety Risk Score *= Exposure x LoRE x Safety CoRE = Frequency x Safety CoRE*

where

- Safety CoRE = 1000 x Safety Weight (50%) x [Scaled Unit of the Safety Attribute]
- Scaled Unit of the Safety Attribute varies from 0 to 100