Review of the Causal Alpha Factor Method

Modeling Common Cause Failures

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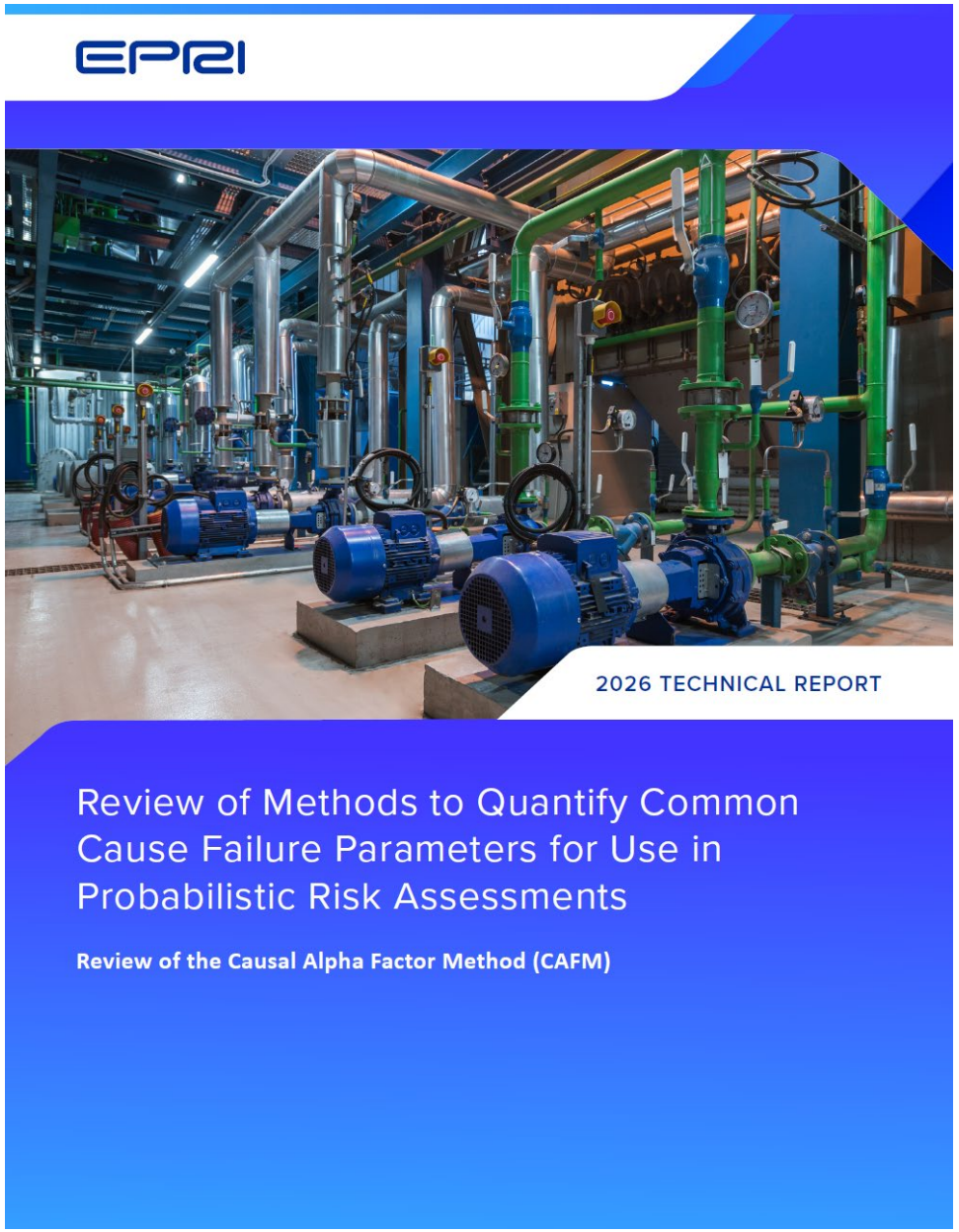
Introduction

- Thank you to Ken Kiper and Josh Beckton of WEC for supporting this research.
- Based on the insights presented in the 2026 EPRI report 3002035183.
- This report provides a comprehensive review of the CAFM method for quantifying common cause failure parameters.



Causal Alpha Factor Method (CAFM)

- **Incorporates failure causes** into CCF modeling to support a more informed assessment of operational events and enhanced risk-informed decision-making.

- Initially intended to support the NRC's event and condition assessments (ECAs) and assess the risk significance of a licensee's performance deficiency.

- **Built on the alpha factor method**, CAFM introduces cause-specific grouping, gamma weighting, and normalization factors to align cause-based estimates with generic CCF parameters.

The New Factors

- The **gamma factor** (γ_i) is defined as the ratio of the total number of component failures due to cause i ($n_{t,i}$) to the total number of component failures (n_t). Gamma is effectively the weighting factor for each CAF parameter.

$$\gamma_i = \frac{n_{t,i}}{n_t}$$

- The **normalization factor** is the ratio of the mean value of the alpha parameter (for all causes) to the sum of the alpha parameters for each of the five causes, weighted by the appropriate gamma factor.

$$NF_{k,i}^{(m)} = \frac{\alpha_k^{(m)}}{\sum_{i=1}^{5}\left(\gamma_i^{(m)} \times \alpha_{k,i}^{(m)}\right)}$$

- Once calculated, the adjusted CAF parameters are calculated to assure that they preserve the all-cause alpha factors.

Cause Groups and Codes

Component (GC)

- Internal to the component, piece-part (IC)
- Setpoint drift (IQ)
- Age/wear (IW)

Design (GD)

- Construction installation error or inadequacy (DC)
- Design error or inadequacy (DE)
- Manufacturing error or inadequacy (DM)

Environment (GE)

- Ambient environmental stress (EA)
- Extreme environmental stress (EE)
- Internal environment (IE)

Human (GH)

- Accidental human action (HA)
- Inadequate maintenance (HM)
- Human action procedure (HP)
- Inadequate procedure (PA)

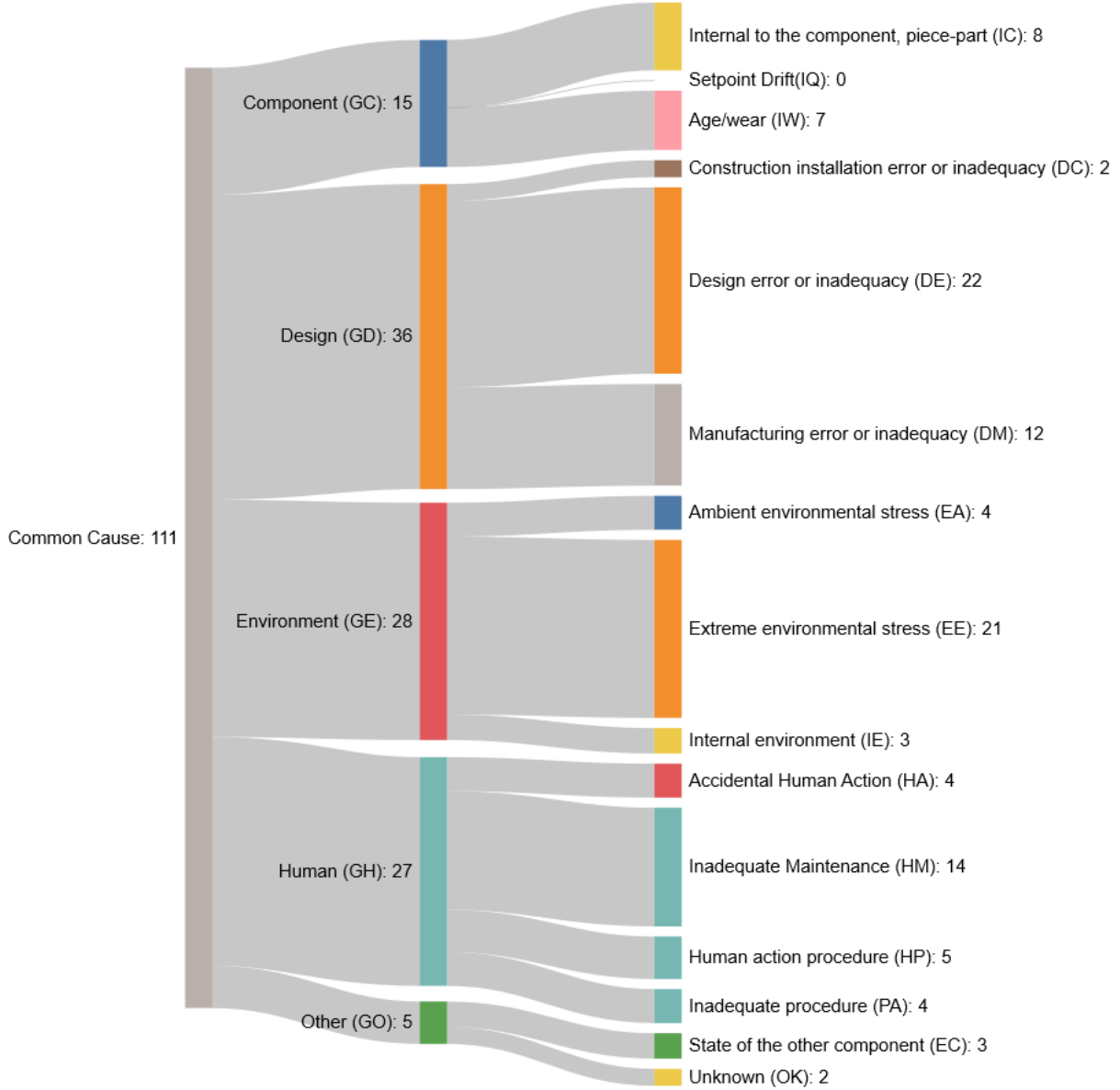
Other (GO)

- State of the other component (EC)
- Other (OT)
- Unknown (OK)

Cause Group and Code Counts

These counts are taken from the RADS/CCF database as presented in April 2025 and includes data from 2006 through 2020. The data includes all component types and failure modes except for the setpoint failure mode.

⚠ Each common cause failure event is assigned to one cause code



Challenges to Consider

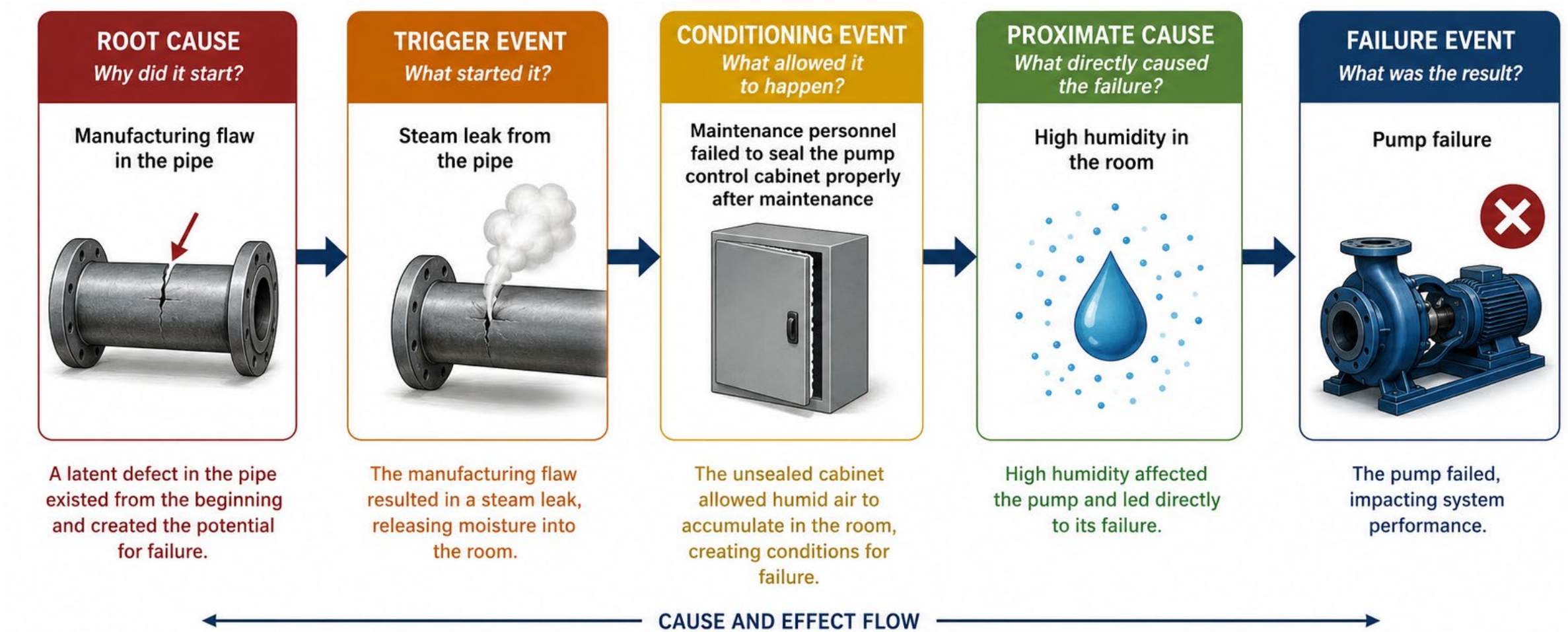
- **Limited Cause-Specific Modeling:** There is a constraint by assigning only one cause per event.
- **Data Limitations:** A significant number of CAFM parameters are dominated by prior distributions due to sparse failure data, especially in subdivided datasets.
- **Mapping-Up Process:** Extrapolating CCF events to larger component groups introduces uncertainty.
- **Wide Uncertainty Distributions:** Many CAFM parameters have large error factors, indicating wide uncertainty.
- **Failure Mode Definitions:** The current dataset includes failure modes that are not well defined or not applicable to parametric common cause modeling.
- **Extreme Environmental Stress:** These events are better modeled as hazard impacts rather than parametric CCFs.

Root Cause vs. Proximate Cause

- **Proximate cause** is the immediate condition readily identifiable as having caused the failure. This could be a symptom of the true root cause.
- **Root cause** is the underlying reason(s) for the failure. The root cause can be more difficult to understand/identify.
- Failure causes found in industry event reports and databases may represent the proximate cause of CCF events, not the root cause.

> To develop a **complete understanding** of the potential for **multiple failures**, it is necessary to identify the **ultimate reason** for the failure.
>
> — NUREG/CR-6268, Rev. 1

The Causal Chain of Failure (an Example)



Based on an example from NUREG/CR-6268, Revision 1

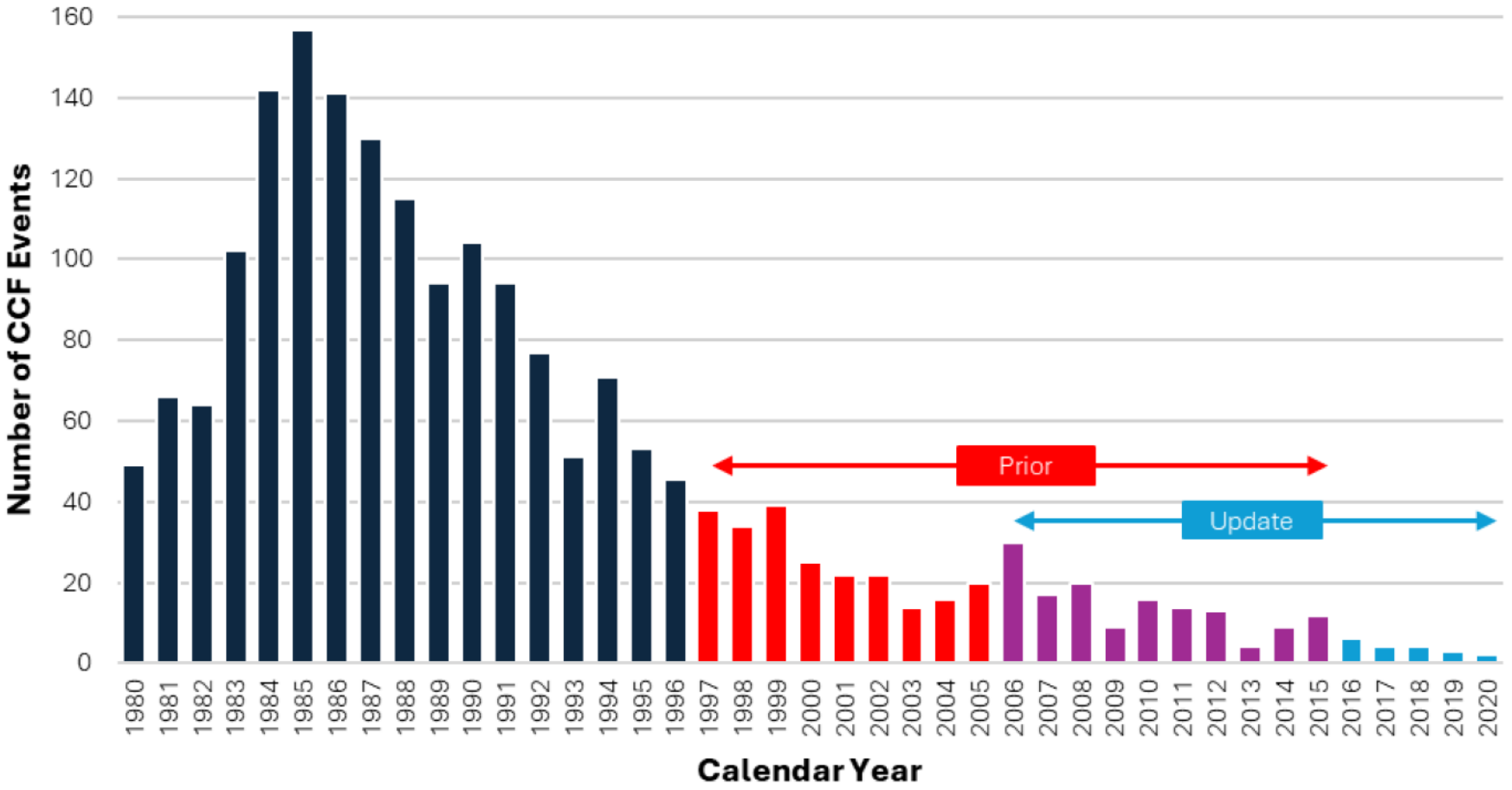
Assigning a Single Cause

- One challenge is the assignment of a single cause to each failure event. This is due (in part) to the difficulties in identifying all conditions resulting in a failure and then utilizing the multiple codes.

- A possible solution could be broader codes that attempt to capture the general condition(s) resulting in a failure.

- Another possible solution is to revise the coding in the NROD database to allow for multiple causes and then assign a weighting factor to each cause.

CCF Event History and Current Trends



Recent CCF experience is limited. When creating additional subdivisions of this data, the prior will dominate the resulting posterior distributions for the CCF parameters.

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