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Development of Good Practices in the Implementation of Common Cause Failure in PRA Models

PSAM 16 Conference

Fernando Ferrante
Program Manager,
Risk & Safety Management

EPRI
June 27, 2022

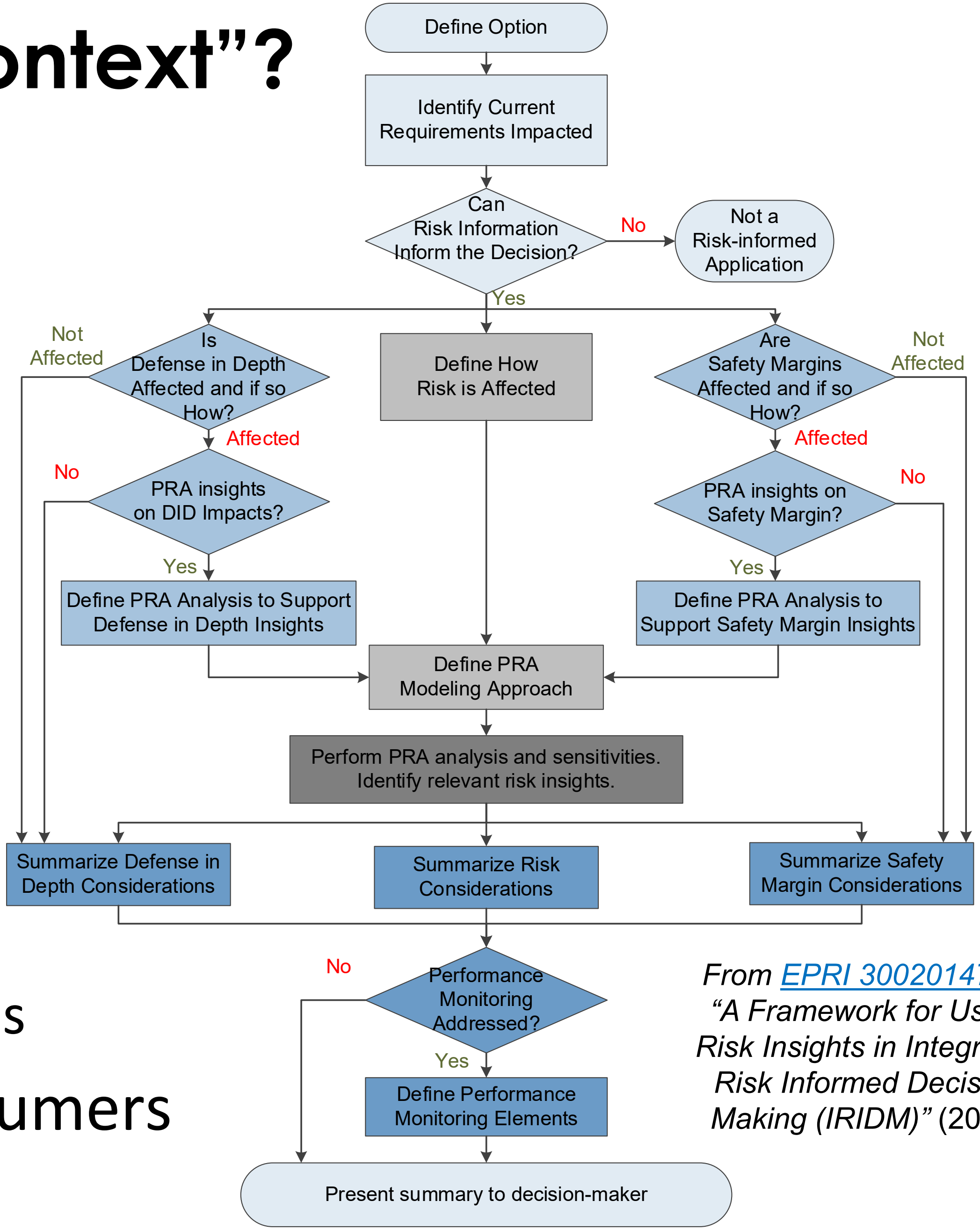
Context of the Effort - Issues Challenging CCF in Practice

- Literature of CCF is spread over several references, often non-practical
- Identification/classification of CCF event data can be non-transparent
  - Typically, non-CCF failures need to be weighted and scaled for CCF estimation
  - A significant amount of expert judgement is used, e.g., choice of prior distributions
  - Data sparseness for some component CCF values continues to be an issue (less so for others)
- Modeling CCF via existing methodologies is non-trivial, non-intuitive
  - Impact of CCF in a PRA model varies with component, system
  - For some risk-informed applications (e.g., Δ risk calculations), impact of CCF in comparison with risk criteria can be outsized, less informed by real world insights
  - Modeling of CCF in larger, complex PRA models is non-trivial (= time, cost)

CCF issue needs <u>better</u> context, <u>not</u> more complexity

What do we mean by “better context”?

- Where does information come from?
  - Need to ensure practitioners understand this
- How is information used?
  - There are technical challenges
  - Often, the challenges are not all technical
- Where is impact of the information?
  - Not all CCF issues are drivers in RIDM
  - Sometimes they are, focus resources
  - PRA models have changed in complexity with regards to treatment of CCF in last decades
- Communicating with risk information consumers is going to continue to be a challenge



From EPRI 3002014783, “A Framework for Using Risk Insights in Integrated Risk Informed Decision Making (IRIDM)” (2019)

EPRI 3002020764 - Structure of Report

SECTION 2: OVERVIEW OF CCF DATA ANALYSIS

- Discuss OpE
- CCF Event ID & Classification
- CCF Methodologies
- CCF Basic Event

SECTION 3: IMPLEMENTATION OF CCF IN PRA MODELS

- Issues in Scope of CCF Modeling
- Inter-system CCF
- SSIE CCF
- Software Aspects

SECTION 4: CCF MODELING IN RIDM APPLICATIONS

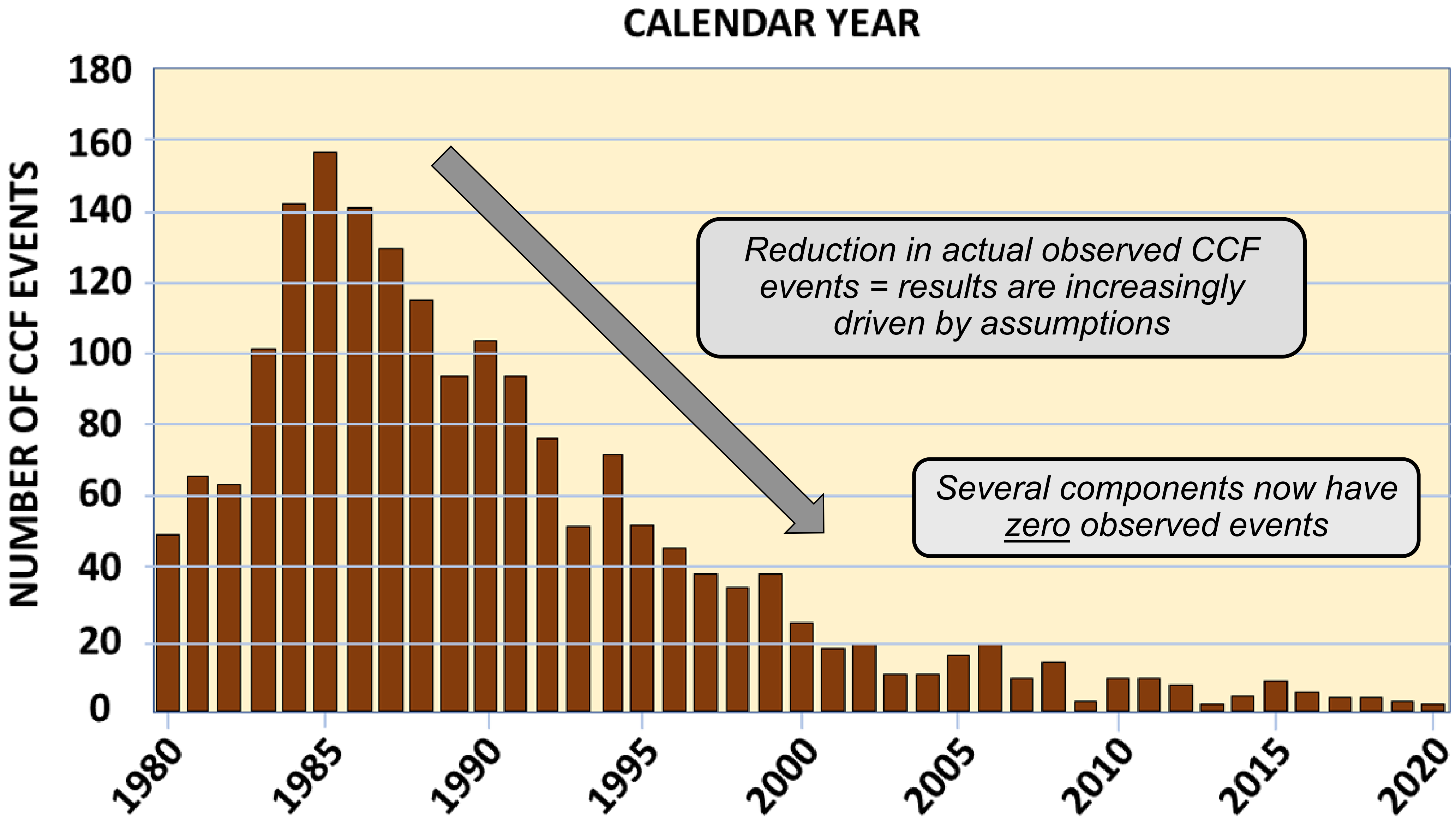
- RIDM Applications
- How CCF is treated
- What is the impact
- Possible Solutions

SECTION 5 & 6: CURRENT PRACTICE & INSIGHTS

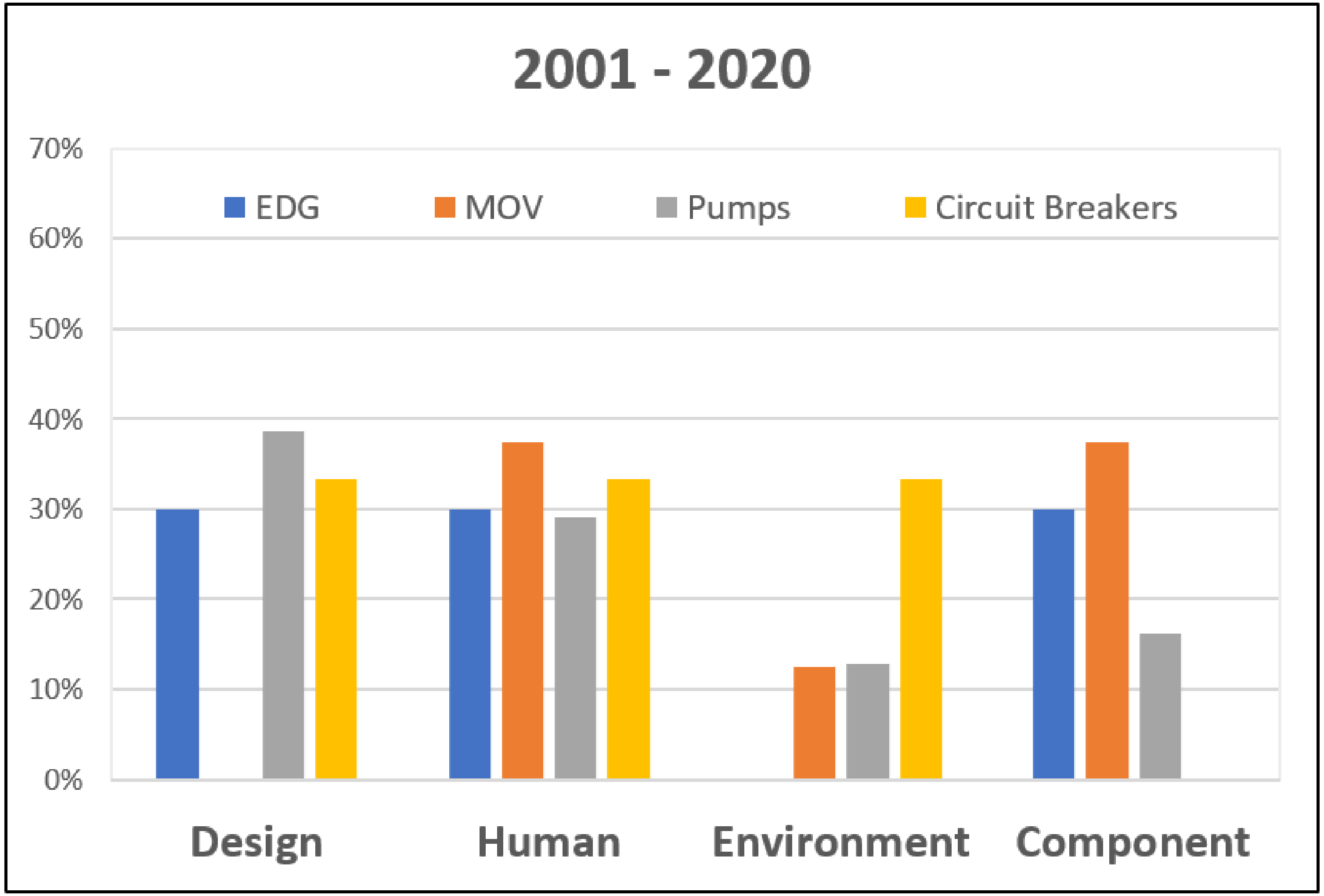
- Insights from current PRA models in US
- CCF Survey from Selected Utilities
- Link between CCF Defenses and Data

- EPRI had done reports on individual issues
- This report connects a large amount of information
  - Major sources of technical basis
  - Includes IAEA guidance
  - Includes software practices
- Section 4 contains practical impacts of CCF on applications
- Section 5 presents state-of-practice in current PRA models
- Section 6 has additional topics

EPRI 3002020764 – Detailed Review of U.S. CCF Data



Trend in Moving Towards Causal Alpha Factor CCF Model



- U.S. NRC developing basis for moving towards a "causal" alpha factor model
- This implies leveraging information about the causes of potential CCF events
- There are many challenges:
  - Further refinement will result in more sparse data
  - Assumptions about prior distributions and other key inputs will need to be re-considered
- More complexity in the data analysis and quantification
  - Better risk insights? TBD

CCF in RIDM – Intra-system vs. Inter-system

- Source of significant debate in update to ASME/ANS Level 1 Standard
- More confusion than clarity on dependencies versus CCF:
  - Does it require **quantitative CCF** modeling (e.g., parametric CCF probability estimation)?
  - What do we mean when we say “inter-system”? Is it:
    - For support system initiating events (e.g., exposed to environmental challenges)
    - For SSCs such as emergency diesel generators, that support multiple other systems
    - For single components in clearly redundant functions (e.g., as in some BWR systems)
- What does the data show? A small number of events on:
  - Extreme environmental events causing cascading component failures
  - An event where water entered the HPCI and RCIC steam supply lines, rendering both turbine-driven pumps inoperable (no CCF events in HCI in the last 20-year period)
- What does current research show? E.g., EPRI 1015096 Investigation of Inter-System CCF
  - Modeling inter-system CCF should be done carefully and methodically (a detailed quantitative parametric CCF probability estimation should not be the first answer, mostly not needed)

CCF in RIDM – CCF Modeling in State-of-Practice PRAs

- Most PRA models use Alpha Factor Model (with some MGL usage)
- A typical model will include **<u>hundreds</u>** of CCF basic events
- **<u>Typical</u>** systems that include CCF basic events:

BWR

- Main Steam, Feedwater
- High Pressure Coolant Injection
- Reactor Core Isolation Cooling
- Residual Heat Removal
- Control Rod Drive System
- Standby Liquid Control System
- Instrument Air
- Automatic Depressurization System
- Reactor Protection System
- SWS, RBCCW & TBCCW
- Emergency Diesel Generator System

PWR

- Auxiliary Feedwater
- Main Steam
- Component Cooling Water
- Chemical Volume and Control System
- Emergency Diesel Generators
- Reactor Protection System
- Service Water System
- Instrument Air

Logically follows from systems with component redundancies or as redundant single trains to other systems (!!!)

CCF in RIDM – CCF Modeling in State-of-Practice PRAs

- A breakdown on CCCG sizes may be approximately:
  - CCCG-2 (**50%**), CCCG-3 (**20%**), CCCG-4 (**20%**), and CCCG-5 and higher (**10%**)
- Majority of CCF basic events assume **non-staggered test**
- Some SSIE CCF modeling may be included for
  - **Loss of CCW**, **Loss of SWS**, **Loss of AC or DC systems**
- Some CCCGs may be modeled across units, for example:
  - **Pumps in CCW/SWS**,
  - **SWS strainers**, and
  - **Emergency Diesel Generators**

CCF in RIDM – CCF Modeling in State-of-Practice PRAs

What are the insights from typical PRA models?

- For an example **PWR**, the following are high risk contributors:
  - **Very small LOCA** with CCF of all **Safety Injection** system **MOVs failing closed**
  - **Very small LOCA** scenario, where the **containment recirculation valves fail closed**
  - **LOOP** event where CCF of **two 125VDC batteries** occur along with other electrical failures
  - **Main steam line break** downstream of the MSIVs, where two MSIVs fail to close

- For an example **BWR**, the following are high risk contributors:
  - CCF of **HPCI/RCIC** pumps and turbines
  - CCF of **4kV AC buses** (contributing to a **SSIE modeled**)
  - CCF of **125VDC buses** (contributing to a **SSIE modeled**)

Details depend on plant-specific, but CCF in general expected in top cutsets of PRA models

EPRI 3002020764 – Good Practices to Support PSA Analyst

- Based on survey of technical sources, data, modeling, software; a set of good practices (not requirements) were identified to help guide CCF modeling

GP1: CCF & Data	GP2: General Screening	GP3: Plant-data Screening	GP4: Active & Passive
GP5: Pooling Data	GP6: CCF in Support Systems	GP7: CCF between Systems	GP8: CCCG Size Limit
GP9: Database Check	GP10: Generic vs Plant	GP11: Generic vs Pooled	GP12: CCF Uncertainty
GP13: Quantify CCF	GP14: CCF for Standby Component	GP15: CCF for Running Component	GP16: Large CCCG Uncertainty

Good Practice 1: Model component types and failure modes as CCCGs when supported by applicable generic data based on number of components and CCF evidence.

Good Practice 2: Good Practice 4: For components with both an active and passive failure mode, screen out the passive failure mode from CCF modeling.

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Good Practice 5:
Good Practice 5: When there is limited CCF data for an individual component type and failure mode in a specific system, consider using pooled data.

Good Practice 8:
Except for steam relief valves or steam safety valves, limit the size of CCCGs unless there is a specific justification for increasing the CCCG size beyond the available evidence.

Conclusions

- U.S. trend is for a continued decrease in "CCF events" with respect to earlier periods of U.S. operating experience
  - This has implications on the modeling and insights from PRA in RIDM
- Complexity of modeling CCF in PRA no longer trivial
- Definition of CCF as "intra-system" or "inter-system" no longer useful
  - Need better treatment, more clear language – not more complexity
- A set of good practices provided (not requirements) informed by:
  - Current state of practice, state of art
  - Understanding of available data
  - PRA software capabilities

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