



# **Risk-Informed Access/Delay Timeline Development**

## **2021 International Topical Meeting on Probabilistic Safety Assessment and Analysis**

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# Overview



- Risk informed timeline development is a new direction to aid in development of access delay timelines
- *What does this new approach do?*
  - Gives a broader understanding of delay performance than traditional timeline development methods
  - Includes probability of both attack timeline and probability of attack success
- *What does this new approach give?*
  - Provides methods to include additional data without throwing out any of the previous work
  - Provides statistically defensible methods for combining SME judgement from multiple sources as well as performance test data

# Traditional Timeline Development



- Timeline developed from performance data
  - Human performance test results of specific tasks (e.g., running climbing, cutting, etc.)
- Most performance data focuses on the quickest time that a task was completed in during performance testing
- When applicable, SME judgement or data can be used with test data to adjust for challenging environments
- Full timeline built from these minimum task times and reported as the delay timeline
  - Conservative approach to minimize risk
  - Backed by commonly accepted performance test data
  - Method minimizes SME judgement for a given task when feasible

# Historical Probability Data for Access/Delay



- For some software tools, probability distributions were desired
- Tools that account for these probabilities range back as far as the late 1970s
- Simplifications were made to ensure computational resources could handle the distribution, as well as to account for limited data
  - Assume fastest performance data was somewhere near the mean
  - Triangle distribution, selected to represent an approximately normal distribution
  - Peak at the reported task time
  - Legs extending +/- 50% of task time in either direction
- Limitations
  - Does not account for non-normal distributions
  - Provided for distribution of task time completions, but did not account for probability of task success
  - Does not address situations where testing was performed by highly capable personnel and was more likely somewhere above average in the distribution

# Risk-Informed Timeline Development



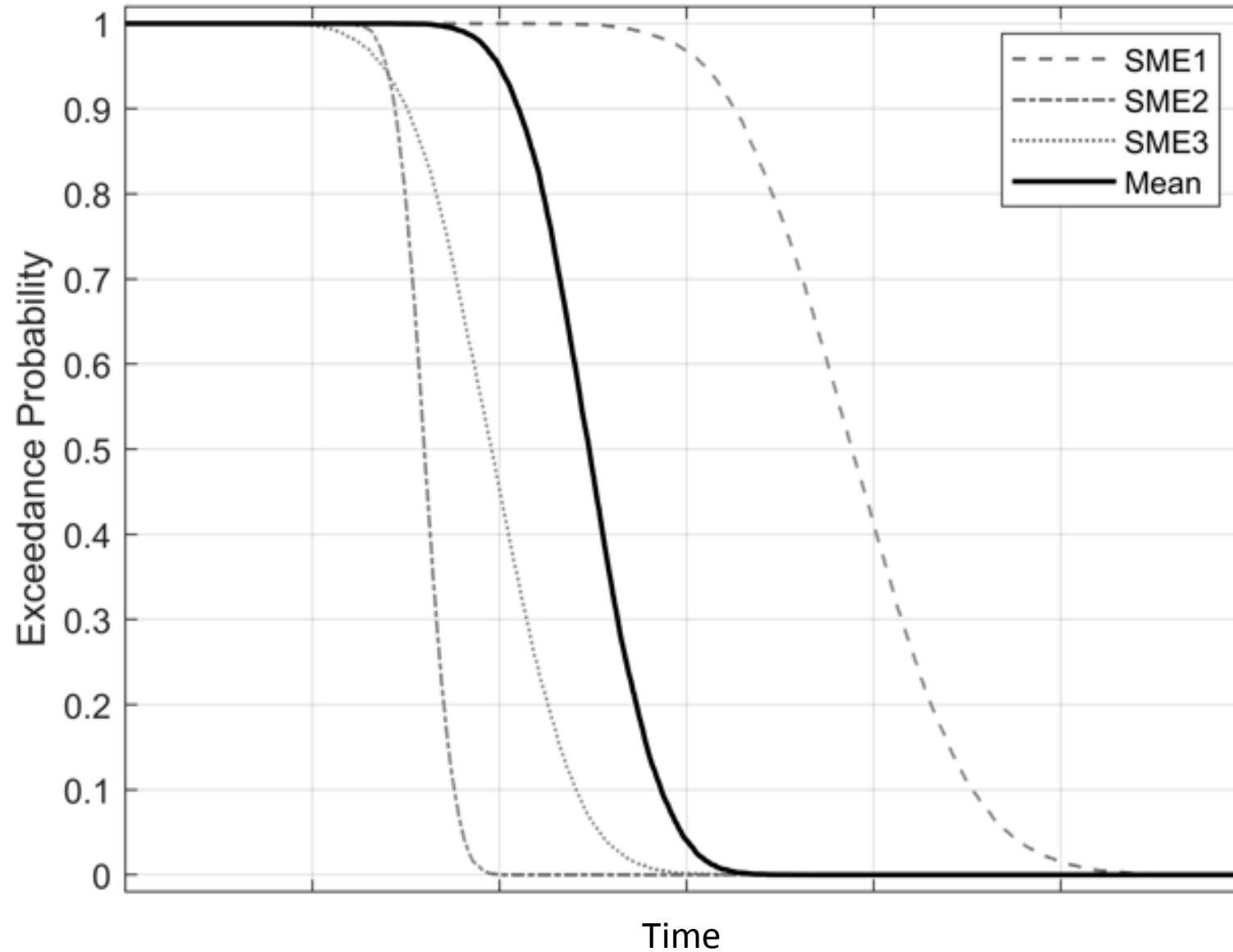
- To develop risk informed timelines, begin with an event tree structure to characterize the underlying tasks
- Next utilize SME judgement to populate those tasks
  - Break timeline down into tasks similar to traditional methods
  - Generate a probability distribution for the time of each task
  - Generate a probability distribution for the success rate of each task
    - Complex tasks where a single tool failure will cause the attack to fail will have a lower probability of success than traversing across an open field
- Then use Bayesian analysis to define uncertainty on the branch points in the event tree
- Use Monte Carlo sampling to propagate the uncertainty in each task through the full timeline
- Once model is based on available information, Bayesian updating can be used to incorporate new test data or new SME judgement into the model while maintaining the previous data

# Bayesian Updating



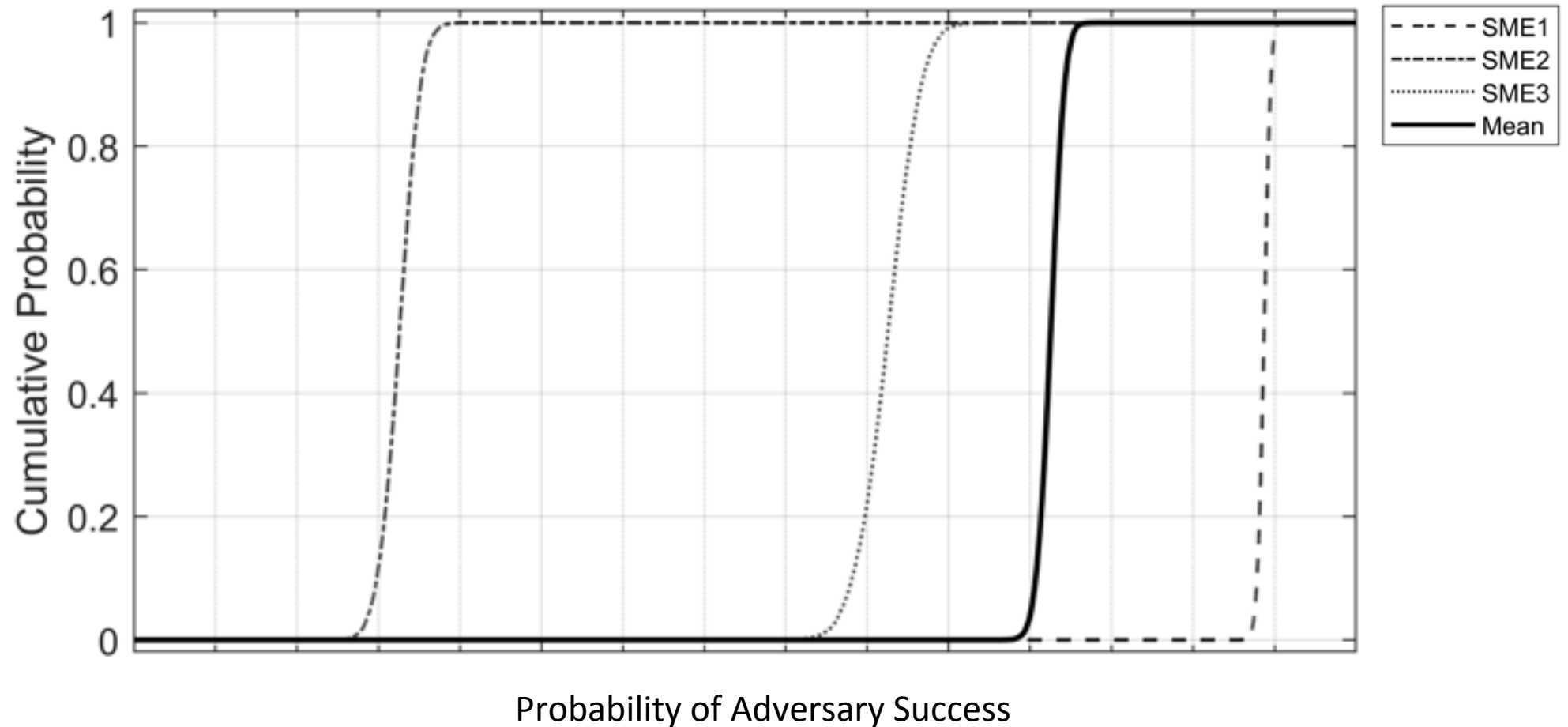
- Bayesian updating is a method to incorporate a prior belief and update it based on additional information that has become available
  - Prior beliefs can be subjective, such as SME judgement, or quantitative, such as previous relevant test data
- Has been widely developed in recent years to support machine learning and artificial intelligence
- While related to machine learning, does not have the same “black box” concerns that other machine learning methods can create
- Bayesian methods can be used with smaller data sets than frequentist methods
  - Due to the costs associated with access/delay tests, this often results in limited data sets

# Event Tree Result: Attack Duration



# Event Tree Results: Probability of Success

*without Bayesian Methods Applied*





# Expected Benefits of Risk-Informed Timelines



- Moving to a risk-informed method allows the focus to move from the attacks that are the fastest, to the attacks that are most likely to succeed
  - Repeat timeline analysis for multiple potential paths
  - Adversaries are going to try to maximize their chance of success, which does not always equate to the shortest timeline
- Provides a broad understanding of which pathways have the most risk associated with them, allowing prioritization of funds for upgrading physical protection systems
  - Focus on the areas where your investment will give the greatest returns on overall system effectiveness
- Provides a method for combining all available data in a statistically sound and consistent way
- Provides more detailed probability distributions for incorporating into modern system evaluation tools
- May allow reconsideration of DBT elements, as with a risk-informed basis it may be feasible to address a wider range of threats, resulting in higher overall system performance

# Next Steps to Realize Value



- Before these methods can be adopted, they will require buy-in from all stakeholders
  - Incorporate feedback and discuss the benefits as well as potential drawbacks with stakeholders
    - Utilities, vendors, NRC, and DOE
    - What can and *cannot* be done with these methods and interpretation of results
  - Run demonstration risk-informed timelines to compare the results of these methods with those of timelines developed using existing methods
  - Evaluate the methods to determine how they can be best applied
- Work with stakeholders to determine how these methods can best be implemented
  - Statisticians and PRA SMEs employing these methods with Security SMEs at sites
  - Incorporating these methods into existing system evaluation tools
    - AVERT, Simajin/VANGUARD, SCRIBE3D, DANTE etc.
  - Develop standalone tools for developing risk-informed timelines
- How does this new approach to timelines align with regulators?
  - NUREG/CR-7145
  - NRC Reg Guide 5.81
  - IAEA NSS Guidance
  - DOE Guidance

# Risk-Informed Access/Delay Timeline Software



RISK INFORMED TIMELINE BUILDER

Start Timeline SME-Data Export

ADD EVENT SAVE

Drag and drop events to reorder

- 1: Breach Outer Fence
- 2: Breach Inner Fence
- 3: Place Explosives at Water Tower
- 4: Detonate Explosives
- 5: Breach Outer Door
- 6: Breach Vault Door
- 7: Set charges on reactor
- 8: Detonate

**Event Details** DELETE

Event Description  
Breach Outer Fence

Additional Notes  
Fence breached with boltcutters

Complication Level  
Low

**Trial Data**

Number of Trials (Numbers Only)  
10

Successes (Numbers Only)  
10

Trial Notes

**Calculation Parameters**

Min Calculation  
Max

Mode Calculation  
Mean

Max Calculation  
Mean

MLE Bound (Numbers Only)  
1

Timeline Builder

RISK INFORMED TIMELINE BUILDER

Start Timeline SME-Data Export

IMPORT SME FILE EXPORT SME TEMPLATE SAVE

**Subject Matter Experts (SME)**

SME 1  
SME 2  
SME 3

**SME Details** DELETE

SME Name  
SME 3

SME Timeline Events

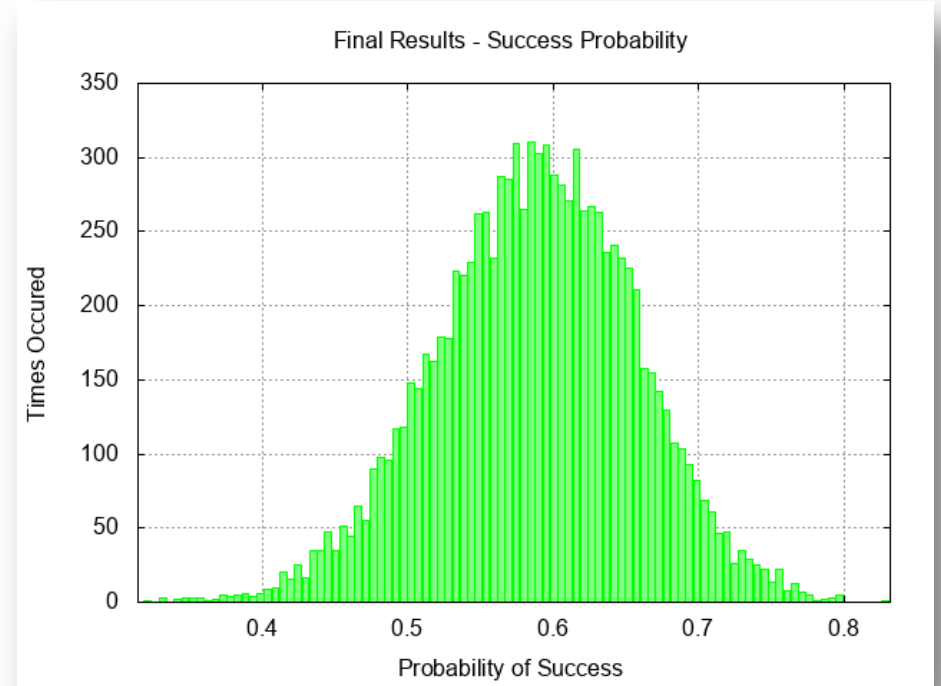
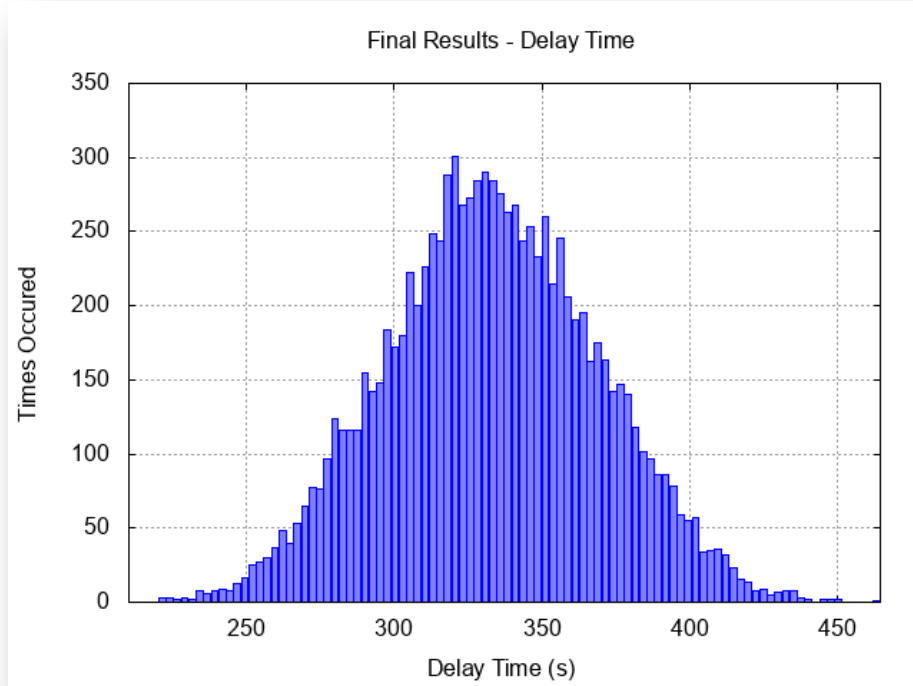
| Event                           | Delay Min | Delay Est | Delay Max | Prob Min | Prob Est | Prob Max | No |
|---------------------------------|-----------|-----------|-----------|----------|----------|----------|----|
| Breach Outer Fence              | 15        | 25        | 35        | 0.99     | 0.999    | 1        |    |
| Breach Inner Fence              | 15        | 25        | 35        | 0.99     | 0.999    | 1        |    |
| Place Explosives at Water Tower | 120       | 240       | 600       | 0.95     | 0.98     | 0.99     |    |
| Detonate Explosives             | 30        | 45        | 60        | 0.99     | 0.999    | 1        |    |
| Breach Outer Door               | 30        | 40        | 50        | 0.999    | 1        | 1        |    |
| Breach Vault Door               | 450       | 900       | 1800      | 0.65     | 0.85     | 0.95     |    |
| Set charges on reactor          | 600       | 1200      | 2400      | 0.6      | 0.8      | 0.95     |    |
| Detonate                        | 30        | 45        | 60        | 0.99     | 0.999    | 1        |    |

SME Input

# Overall Results



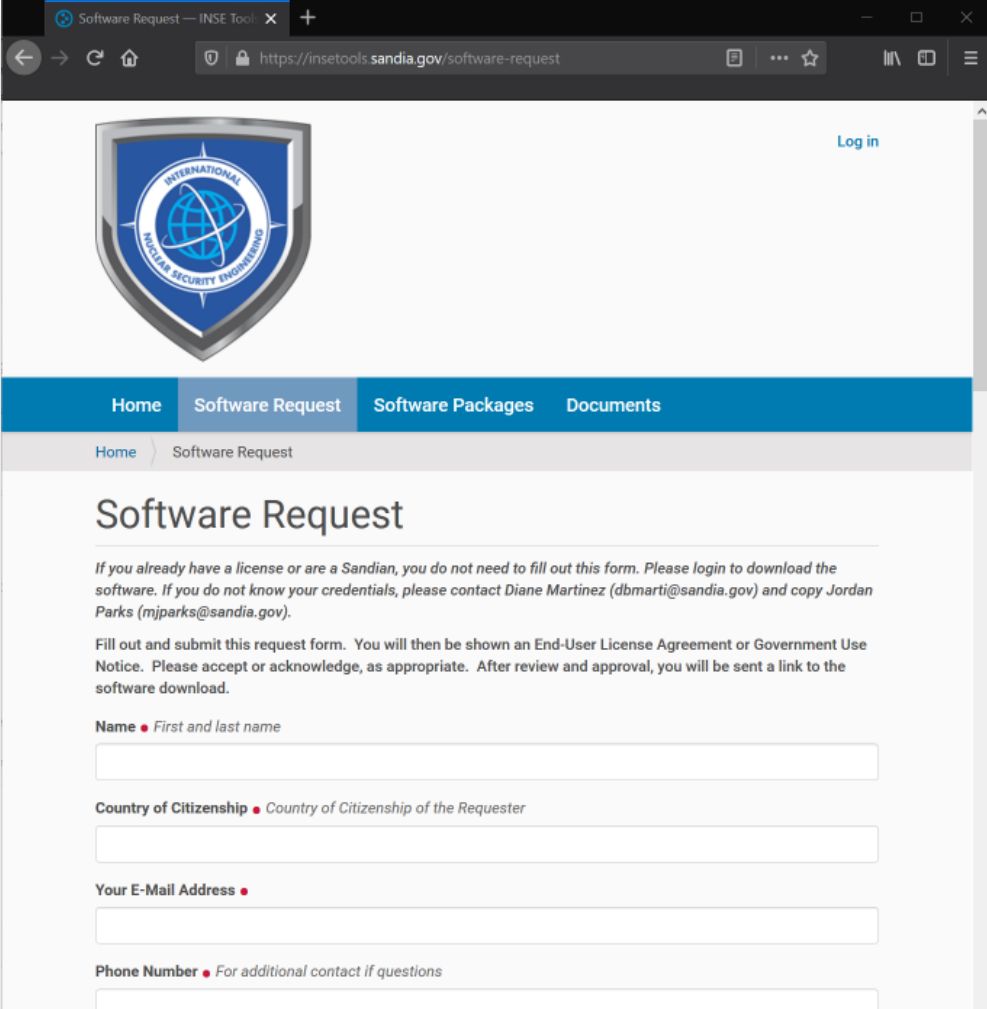
|    | A        | B           | C |
|----|----------|-------------|---|
| 1  | Time (s) | Probability |   |
| 2  | 298.585  | 0.546642    |   |
| 3  | 251.671  | 0.429096    |   |
| 4  | 327.336  | 0.532537    |   |
| 5  | 341.203  | 0.76217     |   |
| 6  | 352.259  | 0.655987    |   |
| 7  | 408.011  | 0.593516    |   |
| 8  | 330.626  | 0.451808    |   |
| 9  | 372.394  | 0.614843    |   |
| 10 | 326.721  | 0.701756    |   |
| 11 | 336.48   | 0.670137    |   |
| 12 | 341.26   | 0.587326    |   |
| 13 | 320.311  | 0.588527    |   |
| 14 | 326.912  | 0.629845    |   |
| 15 | 330.104  | 0.618139    |   |
| 16 | 350.633  | 0.540689    |   |
| 17 | 346.788  | 0.589012    |   |
| 18 | 319.815  | 0.61898     |   |
| 19 | 292.944  | 0.573744    |   |
| 20 | 307.191  | 0.570334    |   |
| 21 | 302.816  | 0.595195    |   |
| 22 | 269.57   | 0.680389    |   |
| 23 | 344.824  | 0.644457    |   |
| 24 | 375.926  | 0.572367    |   |
| 25 | 340.257  | 0.602478    |   |
| 26 | 317.822  | 0.652101    |   |
| 27 | 335.177  | 0.582267    |   |
| 28 | 391.545  | 0.656344    |   |
| 29 | 397.929  | 0.674959    |   |
| 30 | 369.67   | 0.657368    |   |
| 31 | 351.494  | 0.632042    |   |
| 32 | 357.28   | 0.571734    |   |
| 33 | 429.95   | 0.499764    |   |
| 34 | 352.96   | 0.546925    |   |
| 35 | 290.187  | 0.694931    |   |
| 36 | 395.997  | 0.557683    |   |
| 37 | 355.105  | 0.674108    |   |
| 38 | 386.576  | 0.599134    |   |
| 39 | 338.836  | 0.531616    |   |
| 40 | 276.129  | 0.520845    |   |
| 41 | 308.327  | 0.579351    |   |
| 42 | 357.401  | 0.648775    |   |
| 43 | 319.298  | 0.651398    |   |
| 44 | 346.115  | 0.651244    |   |
| 45 | 301.762  | 0.629206    |   |
| 46 | 268.387  | 0.605068    |   |
| 47 | 295.121  | 0.629594    |   |
| 48 | 353.936  | 0.624688    |   |
| 49 | 343.533  | 0.488822    |   |



# Requesting Software

<https://insetools.sandia.gov/software-request>

- Fill out form and select “Risk Informed Timelines” in the software section.
- Sandia will then process the request
  - Usually 2-4 weeks
  - After execution of license, a download link will be sent for the software
  - Software will include a comprehensive user guide.



The screenshot shows a web browser window with the URL <https://insetools.sandia.gov/software-request>. The page features the Sandia logo at the top left and a "Log in" link at the top right. A navigation bar includes links for "Home", "Software Request", "Software Packages", and "Documents". Below this, a breadcrumb trail shows "Home" and "Software Request". The main heading is "Software Request".

*If you already have a license or are a Sandian, you do not need to fill out this form. Please login to download the software. If you do not know your credentials, please contact Diane Martinez (dbmarti@sandia.gov) and copy Jordan Parks (mjparks@sandia.gov).*

Fill out and submit this request form. You will then be shown an End-User License Agreement or Government Use Notice. Please accept or acknowledge, as appropriate. After review and approval, you will be sent a link to the software download.

**Name** • First and last name

**Country of Citizenship** • Country of Citizenship of the Requester

**Your E-Mail Address** •

**Phone Number** • For additional contact if questions

Thanks to Andrew Thompson, Dusty Brooks, and Todd Noel for their efforts in developing this method and software



# Sustaining National Nuclear Assets

*<http://lwrs.inl.gov>*