

# Software Failure and Reliability Assessment Tool (SFRAT): An Open Source Application for the Practitioner and Research Community

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## Motivation

- Many government organizations and national labs depend on mission and life critical software
  - To assure national security
  - Safety of human operators and communities in which software enabled systems reside

Reliability key to success of software



## Motivation (2)

- Department of Defense (DoD) increasingly depends on software intensive systems
  - Mission and life critical
  - Must preserve high reliability and availability
- Urgency to deploy new technologies and military capabilities may result in
  - Inadequate reliability testing
  - Severe economic damage and loss of life



## Background

- Recent National Academies report on Enhancing Defense System Reliability recommends
  - Use of reliability growth models to direct contractor design and test activities
- Several tools to
  - Automatically apply reliability models
  - Automate reliability test and evaluation



# **Existing Tools**

- CASRE (Computer-Aided Software Reliability Estimation Tool)
  - Incorporates SMERFS (Statistical Modeling & Estimation of Reliability Functions for Software)
  - Automatically ranks models according to set of goodness of fit measures
- **Caution:** Users strongly advised to study underlying mathematics
  - Can better inform model selection process

# Shortcomings of existing tools

• Over 20 years old

UMass |

– Not updated in over 15 years

Dartmouth

- Not compatible with current operating systems
- Interface
  - Does not impose intuitive workflow
  - Possible to run models on data that does not exhibit reliability improvement
  - User may fail to recognize lack of model fit
- Not open source (not sustainable)
  - Inhibits dialog between researchers and practitioners

# Software Failure and Reliability Assessment Tool (SFRAT)

• SFRAT is an open source application

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- Designed for practitioner and research community
- Programmed in R and provides functionality through a Shiny graphical user interface
- Reduces the need for knowledge of the underlying statistical techniques
  - Can help contractors quantitatively assess software as part of their data collection and reporting process

# Software Failure and Reliability Assessment Tool (SFRAT) (2)

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- Allows users to answer following questions about a software system during test
  - 1. Is the software ready to release (has it achieved a specified reliability goal)?
  - 2. How much more time and test effort will be required to achieve a specified goal?
  - 3. What will be the consequences to system's operational reliability if not enough testing resources are available?



# SFRAT Output/Deliverables

- Trend tests
- Model rankings
- Visualization
  - Cumulative failure plot
  - Time between failure plot
  - Failure intensity plot
  - Reliability growth plot
- Predictions
  - Time to achieve reliability
  - Expected number of faults for next *t* time units
  - Expected time to next *k* failures



# SRGM classification

- Based on data formats
  - Failure Rate models
    - Inter-failure times time between  $(i 1)^{st}$  and  $i^{th}$  failure, defined as  $t_i = (\mathbf{T}_i \mathbf{T}_{i-1})$
    - Failure times vector of failure times,

$$T = < t_1, t_2, ..., t_n >$$

- Failure Counting models
  - Failure count data length of the interval and number failures observed within it,
  - $< \mathbf{T}, \mathbf{K} > = <(t_1, k_1), (t_2, k_2), \dots, (t_n, k_n) >$



### SFRAT - Tab view

	Software Reliability Assessment in F	R Select, Analyze, and Filter Data Set Up and Apply Models Query Model Results Evaluate Mo
Select, Analyze, and Subset Failure Data	Plot	Data and Trend Test Table
Specify the input file format		
Excel (.xlsx)      CSV (.csv)	Open, analyze, and	subset file
Select a failure data file		Apply models plot results
Choose File No file chosen		apply models, plot results
Please upload an excel file		
Choose a view of the failure data.		Detailed model queries
Cumulative Failures	~	
Draw the plot with data points only, lines only, or both?		Evaluate model performance
Both O Points O Lines		
Plot Data or Trend Test?		
Data Trend test		
sood data onon rondomy growth.		
Laplace Test		
♣ Save Display		
Subset the failure data by category or data range		
Select one or more failure categories to retain		
0	6	
	5	
Specify the data range to which models will be applied.		

## Input File Format

- Excel or csv
- First row indicates type of failure data
  - FN Failure number
  - IF Inter failure times
  - FT Failure times
  - FC Failure count
- Regardless of input format
  - Tool converts data to other two formats

1	FN	IF	FT
2	1	3	3
3	2	30	33
4	3	113	146
5	4	81	227
6	5	115	342
7			



## Tab 1 Select, Analyze, and Filter data



## Tab 1 – After data upload

Select Applyze, and Subset Failure Data	Plot D	Data and Trend Test Table				
Select, Allalyze, allu Subset Fallule Data			Cumulative	e Failures vs. Cumulative Test	Time of SYS1	
Specify the input file format						
Excel (.xlsx)      CSV (.csv)						
Select a failure data file						
Choose File model_data.xlsx Upload complete						
Choose Sheet					۲۲	
SYS1 ·						
Choose a view of the failure data.				کی	 	
Cumulative Failures						
Times Between Failures	100 -					
Cumulative Failures				,		
				1		
Plot Data or Trend Test?						
Does data show reliability growth?						
	Inces	کی				
Specify the confidence level for the Laplace Test	r of Fa	7				
0.9	Numbe	لم الم				
	lative	لے				
Choose the type of file to save plots. Tables are saved as CSV files.	Cum	e e e e e e e e e e e e e e e e e e e				
○ JPEG ○ PDF ● PNG ○ TIFF		ſ				
L ▲ Save Display		r <sup>g</sup>				
	50 -					
Subset the failure data by data range		r <sup></sup>				
Specify the data range to which models will be applied.		£				
1 136		ſ				
1 35 69 102 136		ſ				
		ſ				

#### Cumulative failure data view



## Laplace trend test – SYS1 data



(application of SRGM appropriate)



## Laplace trend test – J4 data



Does not exhibit reliability growth (additional testing required)

## Dartmouth UNIVERSITY OF MASSACHUSETTS DARTMOUTH Running Arithmetic Average – SYS1 data

U





## Tab 2 Set Up and Apply Models



### Tab 2 view

Configure and Apply Models	
Specify the number of failures for which the models will make predictions	
Specify for how many failures into the future the models will predict	
1	* *
Choose one or more models to run, or exclude one or more models.	
Delayed S-Shape Geometric Goel-Okumoto Jelinski-Moranda Weibull	
Run Selected Models	
Display Model Results	
Choose one or more sets of model results to display.	
No model results to display	
Choose the type of plot for model results.	
Groose a piot type	
Cumulative Failures	•
Cumulative Failures For how much time should the model results curve extend beyond the last prediction point?	•
Cumulative Failures For how much time should the model results curve extend beyond the last prediction point? 10000	•
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### Cumulative failures



### Plot enables comparison of data and model fits



### Time between failures



Times between failures should increase (indicates reliability growth)



## Failure intensity



Model — Delayed S-Shape ---- Geometric --- Goel-Okumoto - - Jelinski-Moranda ---- Weibull

Failure intensity should decrease (indicates reliability growth)



# Reliability growth curve



#### Can determine time to achieve target reliability



## Tab 3 Query Model Results



# Tab 3: Model predictions

- Allows users to answer the following questions
  - 1. How much time will be required to observe the next N failures
  - 2. How many failures will be observed over the next N time units?
  - 3. How much more test time to achieve a specified reliability?



# Tab 3 Options

Make Detailed Predictions From Model Results	
Choose one or more sets of model results to display.	
Delayed S-Shape Geometric Goel-Okumoto Jelinski-Moranda Weibull	
How much time will be required to observe the next N failures	
Specify the number of failures that are to be observed.	
1	-
How many failures will be observed over the next N time units?	
Specify the amount of additional time for which the software will run.	
4116	\$
How much more test time to achieve a specified reliability?	
Specify the desired reliability.	
0.9	\$
Specify the length of the interval for which reliability will be computed	
4116	-
Save detailed model results as PDF or CSV?	
▲ Save Model Predictions	



## **Failure Predictions**

All     All     All     All       1     Image: All image:	
2 Delayed S-Shape 12401.1541529981 0.246856262199/99 1 NA	
3	
4 Goel-Okumoto 62829.7672027733 0.903615409906593 1 4591.28466949961	
5	
6 Jelinski-Moranda 59915.2917457156 0.85612548252314 1 4869.80650205625	
7	
8 Weibull 259865.770847692 1.72595369956707 1 2353.05254648438	
9	
10         Geometric         1592716.45936287         1.87747308675807         1         2170.03088926781	

Showing 1 to 10 of 10 entries

Previous 1 Next



## Tab 4 Evaluate Models



# Tab 4 Options

Evaluate Mode	l goodness of fit	and Applicability
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Choose one or more models for which the results will be evaluated.

Choose one or more sets of model results

Delayed S-Shape Geometric Goel-Okumoto Jelinski-Moranda Weibull

Specify the Percent Data for PSSE

0.9

Save model evaluations as PDF or CSV?

CSV 

 PDF

La Save Model Evaluations

#### Model assessment based on AIC and PSSE



## AIC and PSSE

	Model	$\frac{\mathbb{A}}{\mathbb{V}}$	AIC	2.♦	PSSE 🛊
	All		All	All	
1	Delayed S-Shape		2075.1463153322	22	296.349252292955
2	Geometric		1937.0341742510	06	84.3270812346017
3	Goel-Okumoto		1953.6130663098	84	23.0712869112105
4	Jelinski-Moranda		1950.5341316795	56	19.6003726994455
5	Weibull		1938.1606697580	77	74.9449562450499
Showing	1 to 5 of 5 entries				Previous 1 Next

#### Lower values preferred



## **Conclusions and Future Research**

- Presented open source application to promote collaboration among
  - Members of software reliability research community
  - Users from industry and government organizations
- Application architecture enables integration of models from research literature
- Future research will expand architecture to enable models for other stages of SDLC



# Software Reliability Tool

Available online http://sasdlc.org/lab



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