TSU CONS Reliability

Progress Meeting - #5

Study workflow
Steps followed in the reliability analyses in BISv2

Failure Rate prediction

- 217Plus standard
- Completed with automated tools & Isograph.

Outcomes:
Estimation of failure likelihoods for individual components, system and sub-systems.

Failure Modes apportionment

- Sources:
  - FMD-91 (after MIL-HDBK-338B [1])
  - FMD-2016 [2]
  - Expert knowledge
- Final table in [3]

Outcomes:
Failure modes (e.g., capacitor open, short) with assigned probabilities.

End-effects assignment

- Provided by system expert.
- Discussed with reliability expert

Outcomes:
Establishing probability for each failure end-effect (that are then comparable with risk matrices).

Failure Rate prediction

- 217Plus standard
- Completed with automated tools & Isograph.

→ TSU Board

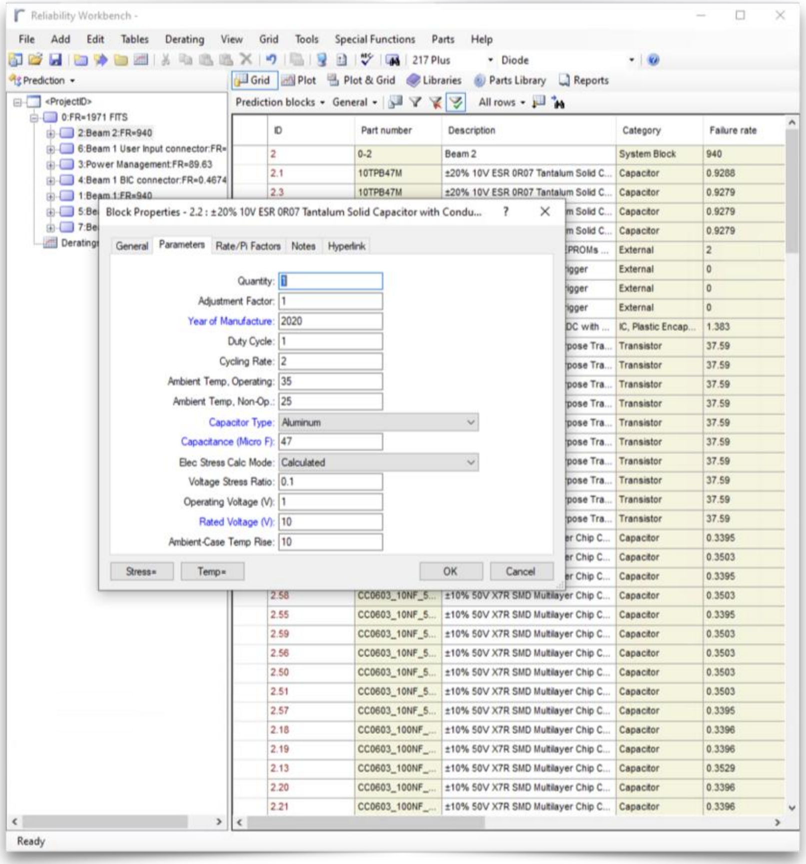
→ TSU RTM Board

Failure rate prediction

The first step of the analysis

Failure rate prediction
217Plus standard & Isograph

- **Objective:** establishing probabilities of failure for individual components.
- **217Plus: 2015 & Isograph:** completed by using 217Plus models [4] in Isograph [5], aided by automated scripts processing design files [6].
- **Failure models:** combine empirical data with physics-of-failure models, being adjustable for specific environmental and operational conditions.
  - Factors like temperature, voltage, environment adjustable for components depending on the category
  - Certain parameters can be set globally to apply to all components (see next slide).



Screenshot of Isograph Reliability Workbench [2]
(tool used for FMECA analysis)

Assumptions
Global parameters and mission profile

Year of manufacture: 2020

Duty cycle: 1 (i.e., always on)

Cycling rate: 2 (i.e., two power cycles in a year)

Ambient temperature, operating: 35

Ambient temperature, non-operating: 25

Relative humidity: 0.5

2.2.1.1 *Global Constants*

Several variables are common to all 217Plus™ component models. These are known as global parameters. These global parameters are as follows:

Y = Year of manufacture

D = Duty cycle (the percent of calendar time that the system in which the component is operating is in an operational state)

T_{AO} = Ambient temperature, operating (in degrees C)

T_{AE} = Ambient temperature, nonoperating (in degrees C)

CR = Cycling rate (the number of power cycles per year to which the system is exposed). In this case, it is assumed that the system transitions from a nonoperating environment to an operating environment at the same time that the power is applied.

RH = Relative humidity

Excerpt from the 217Plus document [7]

Parts assumed to be used within their ratings, no modifications made to quality and process factors (217Plus standard assumed).

Failure Rate prediction

- 217Plus standard
- Completed with automated tools & Isograph.

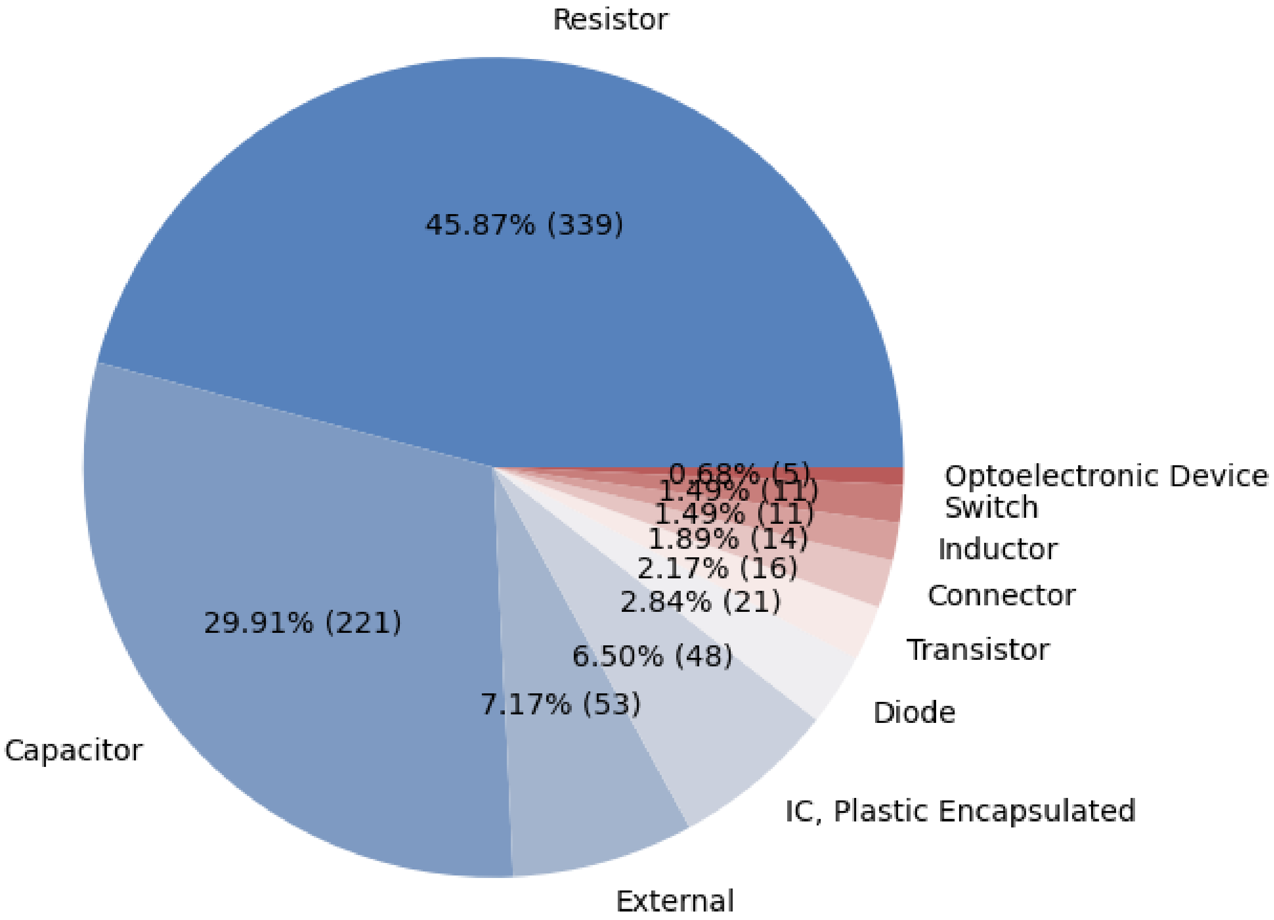
TSU Board

TSU RTM Board

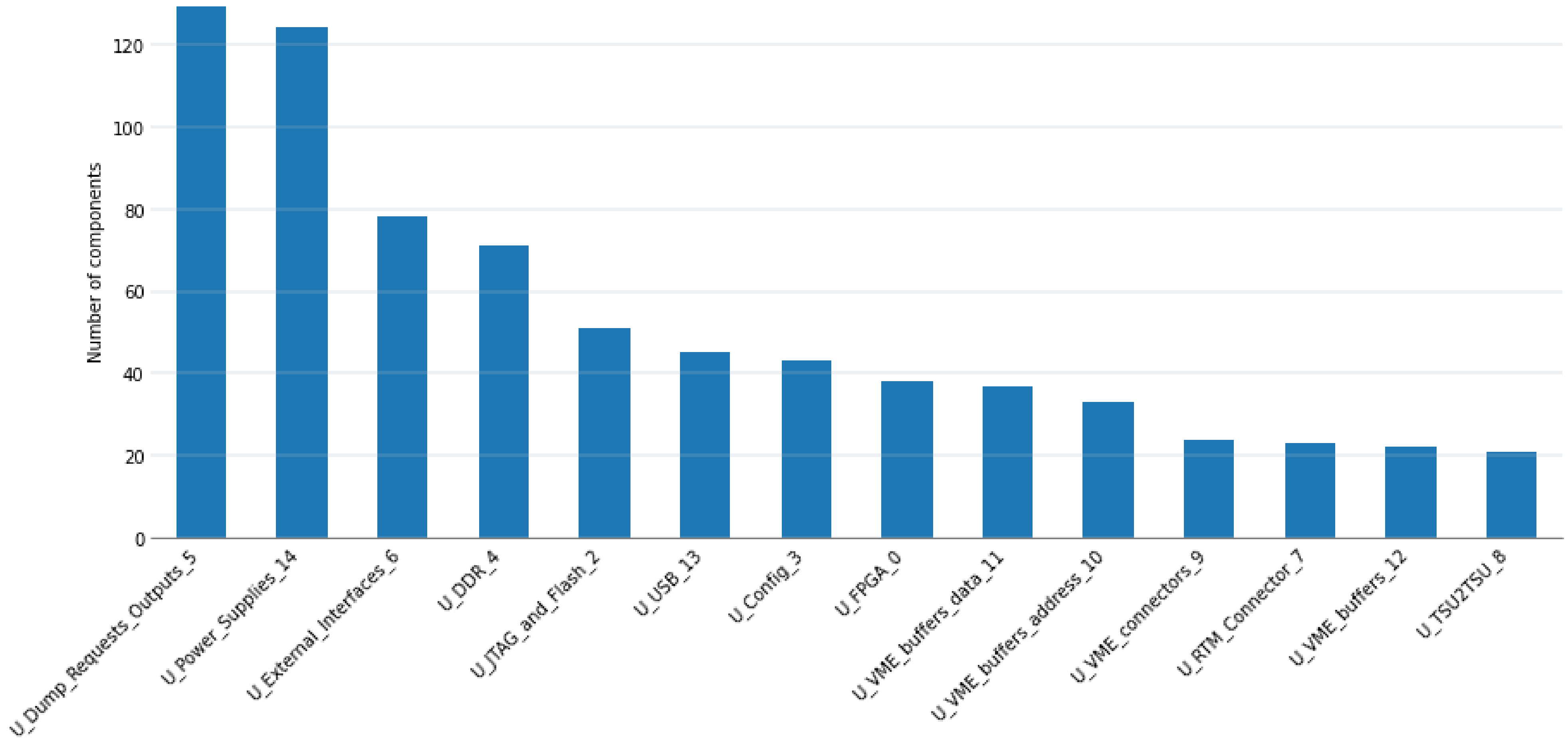
Trigger Synchronization Unit Board

Statistics of the project and preliminary failure rate estimation

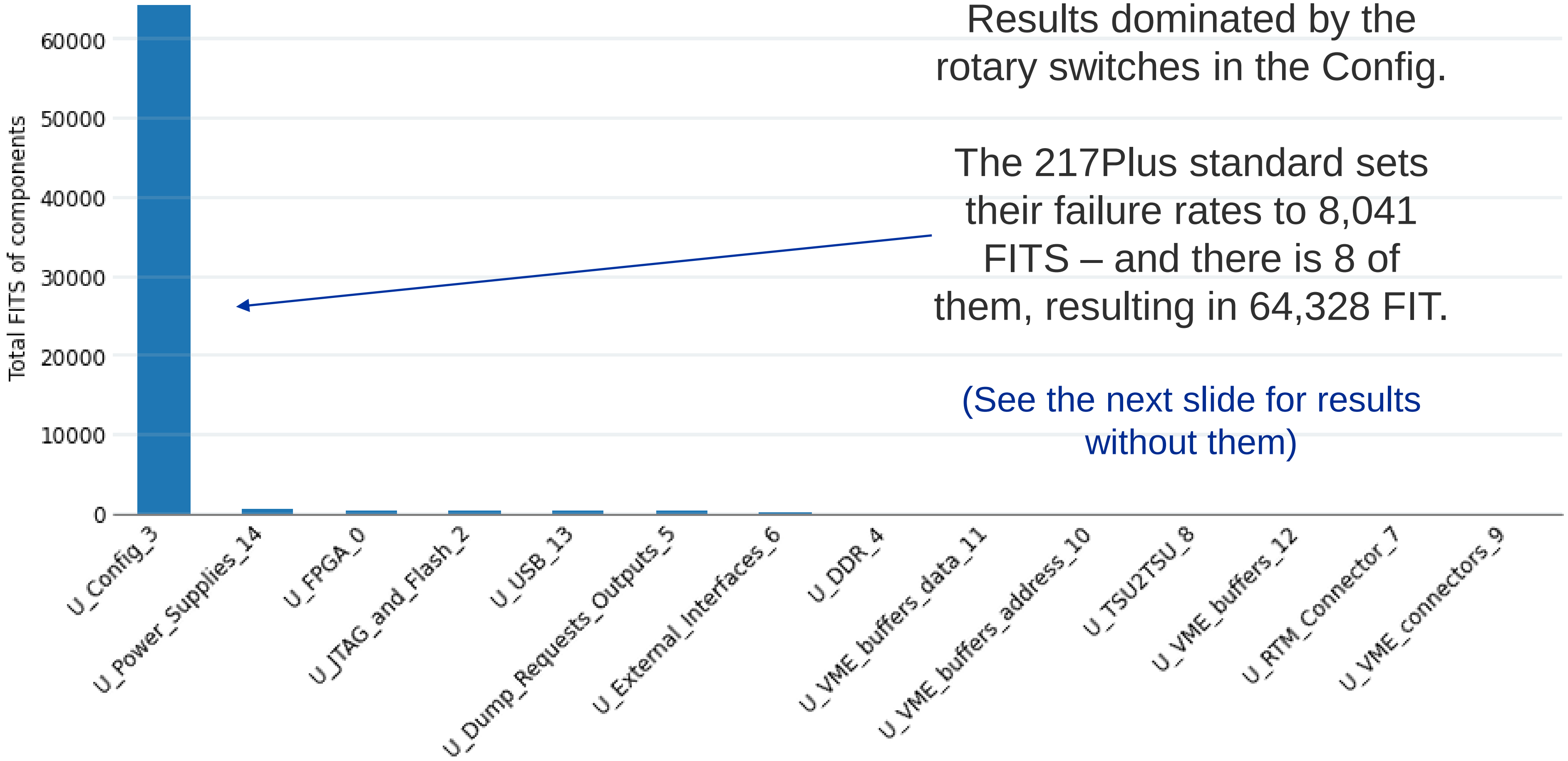
Number of components in categories
Total number of components: 739



Distribution of components across pages
Total number of components: 739



Total FITS of design pages
Total FITS of components in a given page (66,997)



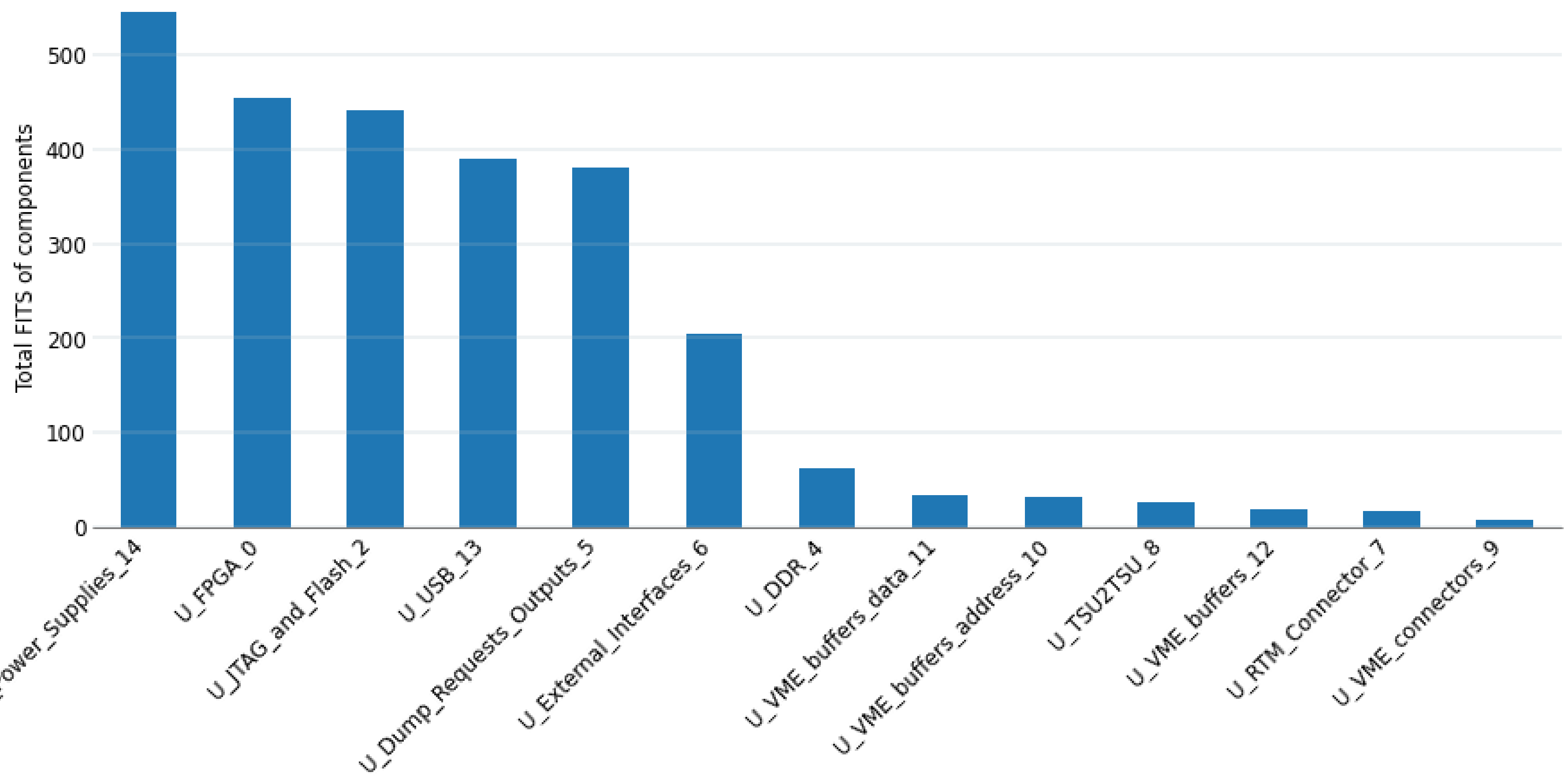
Results dominated by the rotary switches in the Config.

The 217Plus standard sets their failure rates to 8,041 FITS – and there is 8 of them, resulting in 64,328 FIT.

(See the next slide for results without them)

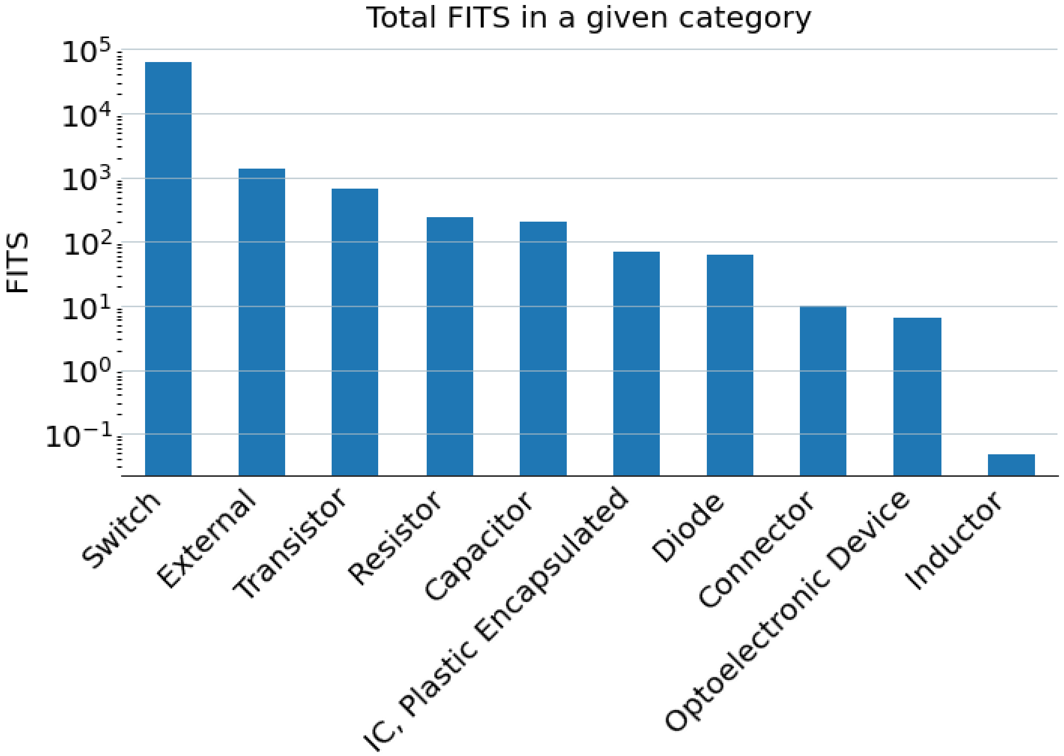
Total FITS of design pages (w/o U_Config)

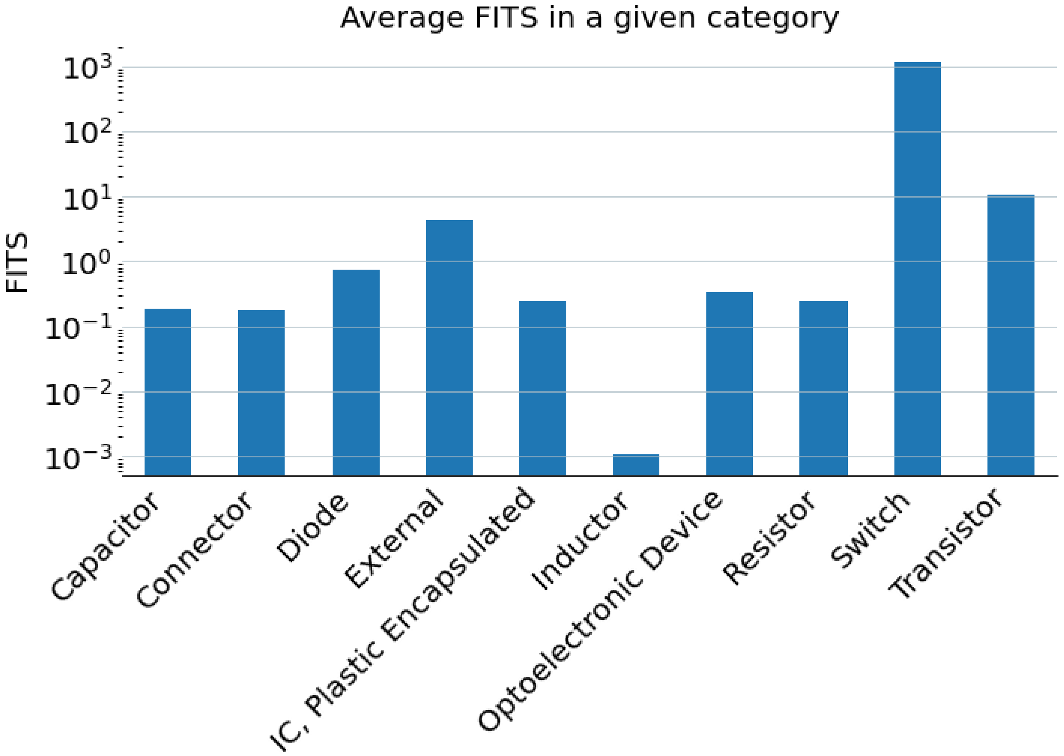
Total FITS of components in a given page (2,618)



FITS of component categories

Distribution of number of predicted failures in 10^9 hours across categories





Failure Rate prediction

- 217Plus standard
- Completed with automated tools & Isograph.

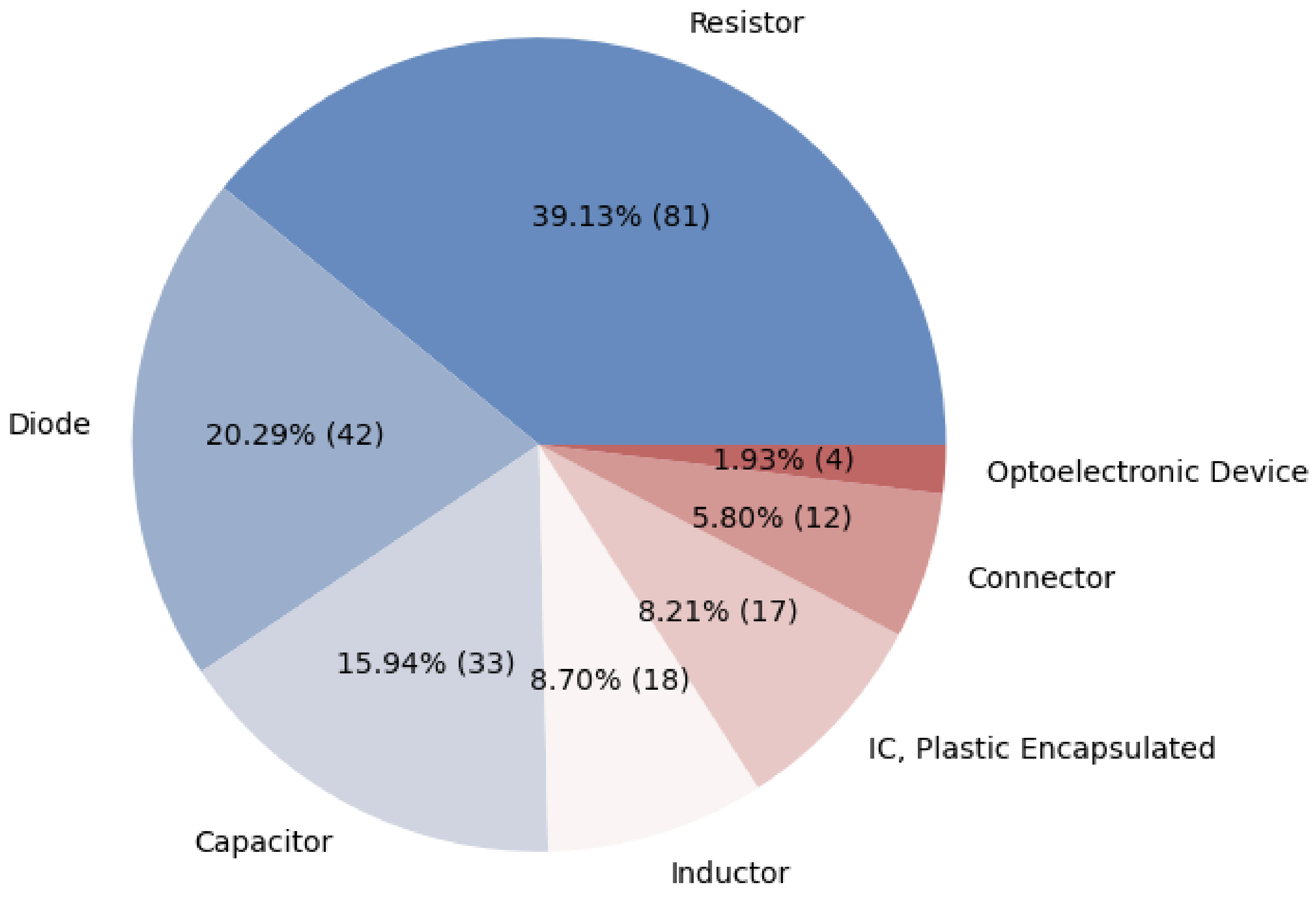
TSU Board

TSU RTM Board

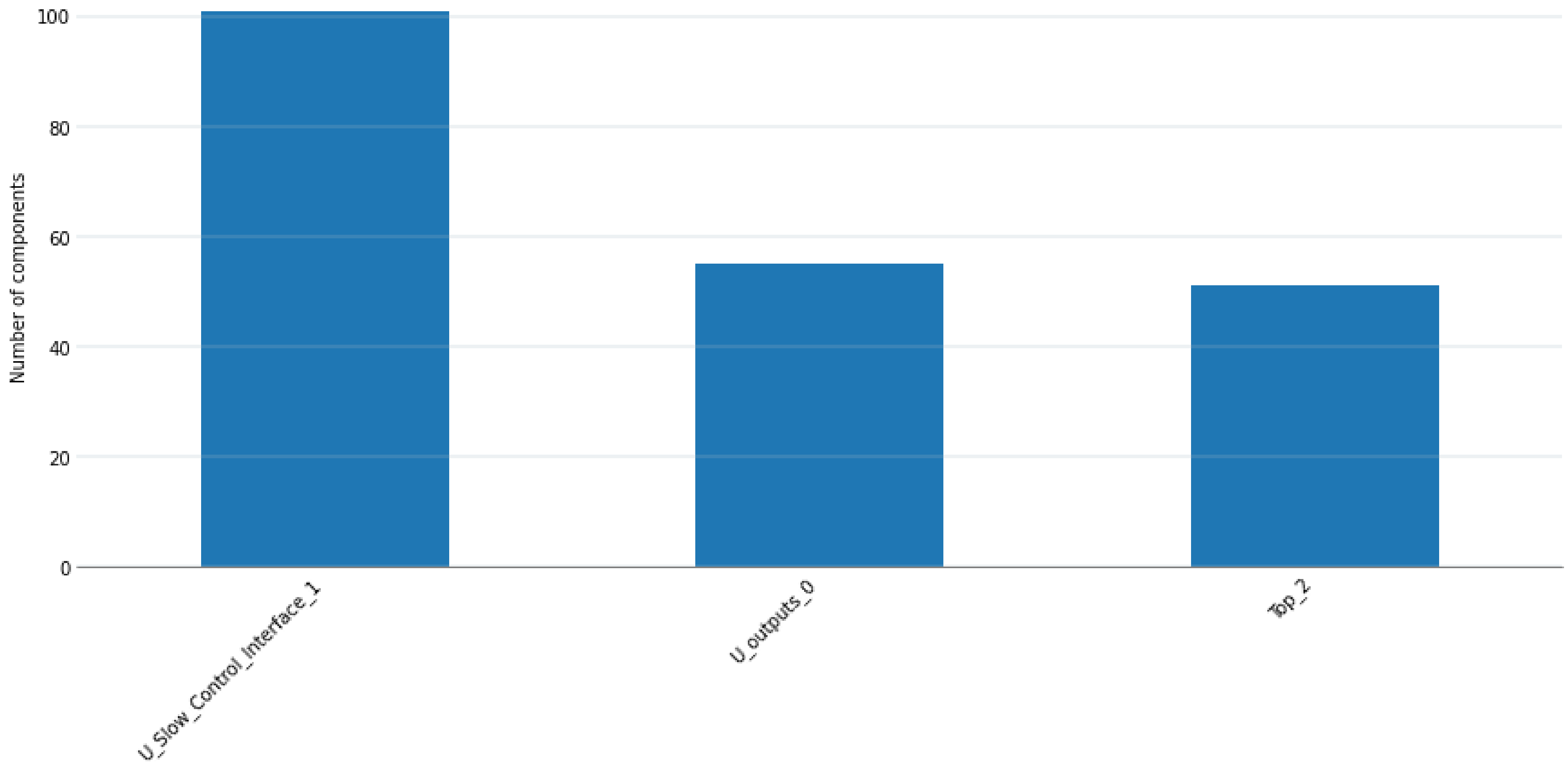
TSU Rear Transition Module Board

Statistics of the project and preliminary failure rate estimation

Number of components in categories
Total number of components: 207

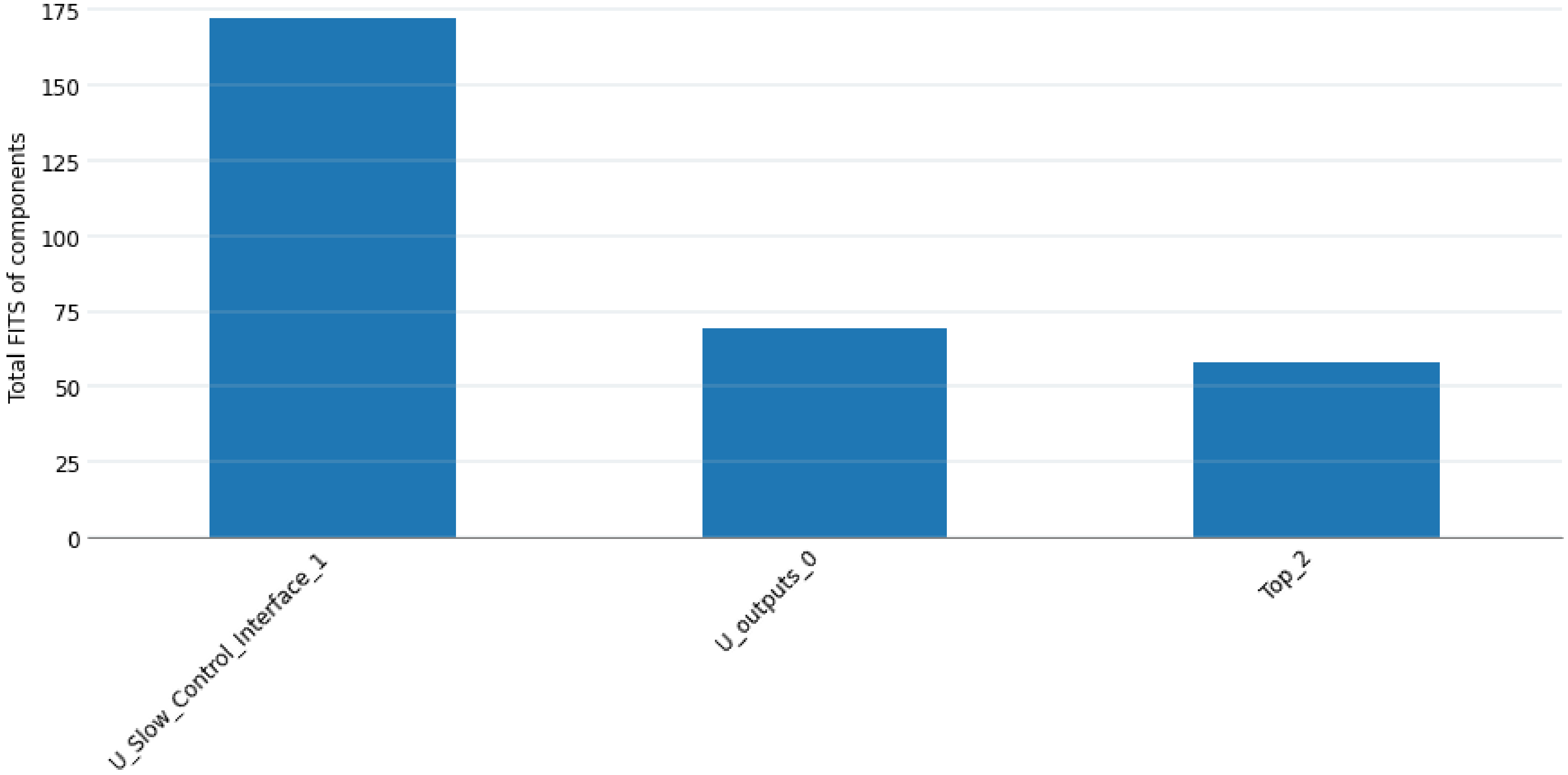


Distribution of components across pages
Total number of components: 207



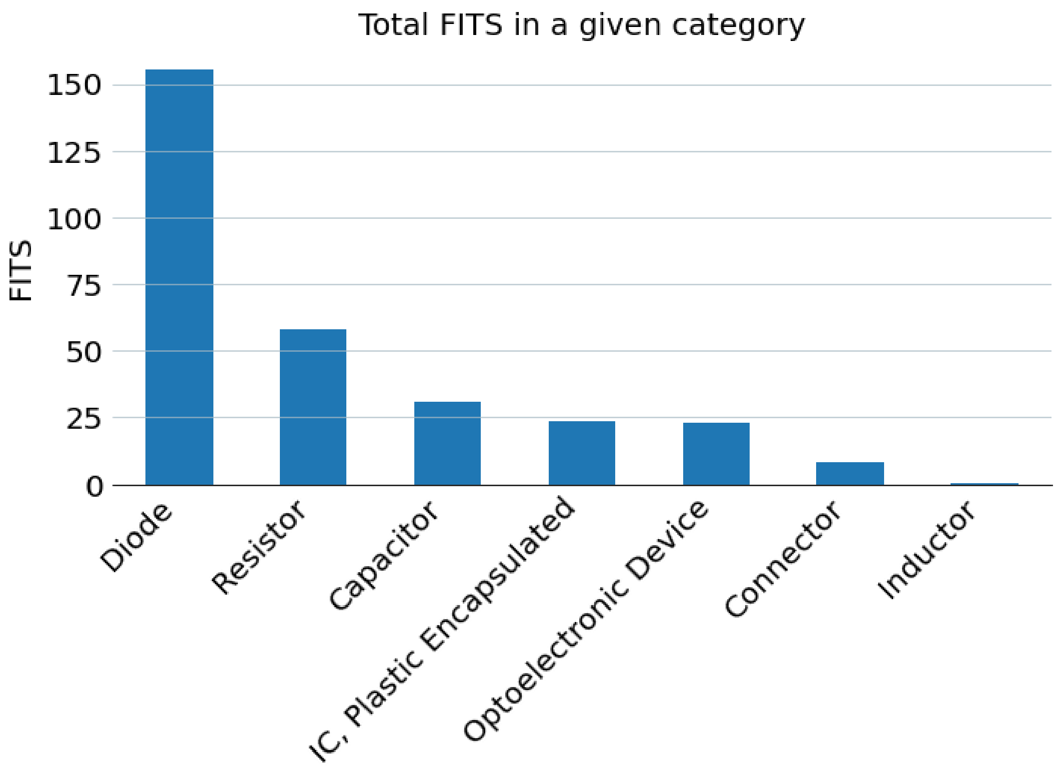
Total FITS of design pages

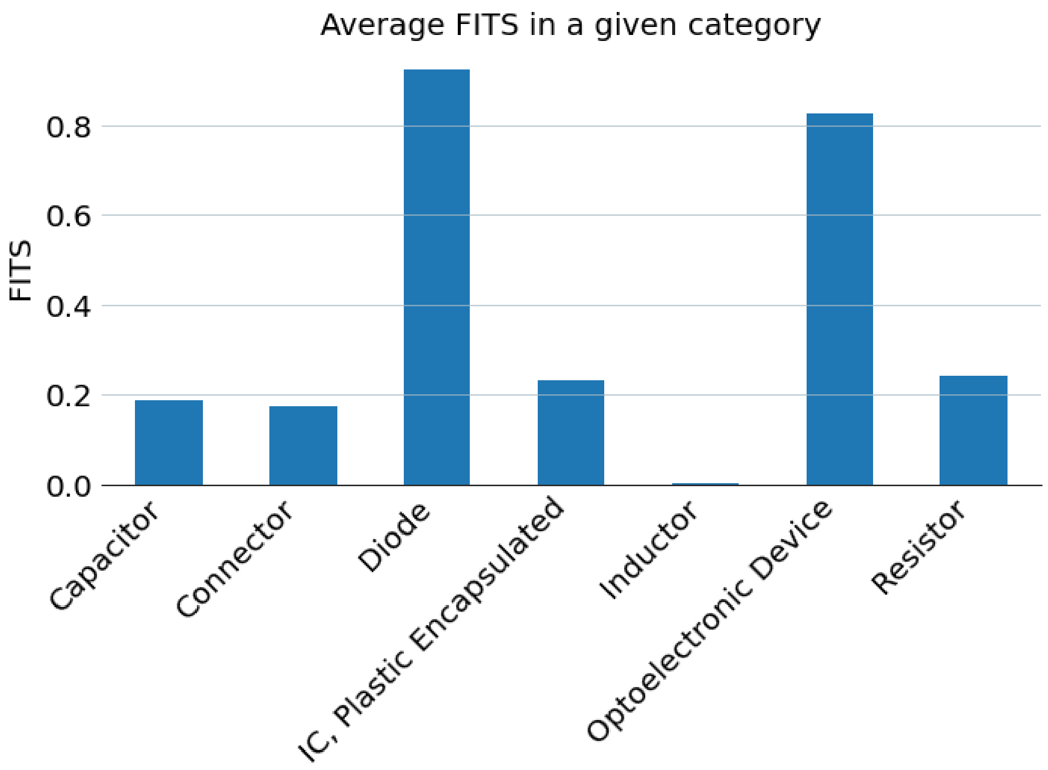
Total FITS of components in a given page (299)



FITS of component categories

Distribution of number of predicted failures in 10^9 hours across categories





Failure rate prediction summary
Conclusions of the first step

The total failure rates are the following:

- **TSU Board:** 2,618 FIT (w/o rotary switches).
- **TSU RTM Board:** 299 FIT.

Results comparable to boards of similar size in BISv2 project.

Continuing the analysis to establish single points of failure as individual failure modes leading to critical failures could **further the confidence in the reliaiblity** by decreasing (potentially) the estimations **by orders of magnitude**.

Next steps

Failure mode apportionment and end-effects

Failure Modes apportionment

- Sources:
  - FMD-93 (from MIL-HDBK-338B [1])
  - FMD-2016 [2]
  - Expert knowledge
- Final table in [3]

→

End-effects assignment

- Exclusively relaying on expert knowledge of the system.

Failure mode apportionment
Based on FMDs and past experience

Objective:

- Identify failure rates for different end-effects (defined in top-level FMECA)
- Exclude possibility of common mode blind failures (across paths A & B)
- Weigh the trade-offs between end effects (e.g. false async vs. blind single path)

Emprical data: Completed by using models apporting overall failure rate to individiual modes based on field data, such as FMD-91 and FMD-2016.

Example

- Capacitor C1, failure rate 2.49 FIT:
  - Short (30%) – 0.7 FIT.
  - Parameter change (61%) – 1.5 FIT.
  - Open (6%) – 0.1 FIT.

End Effects from Top-Level FMECA

- sync beam dump
- async beam dump
- missed beam dump
- no timestamp for Post Mortem, IPOC, etc.
- downtime

End-effects assignment

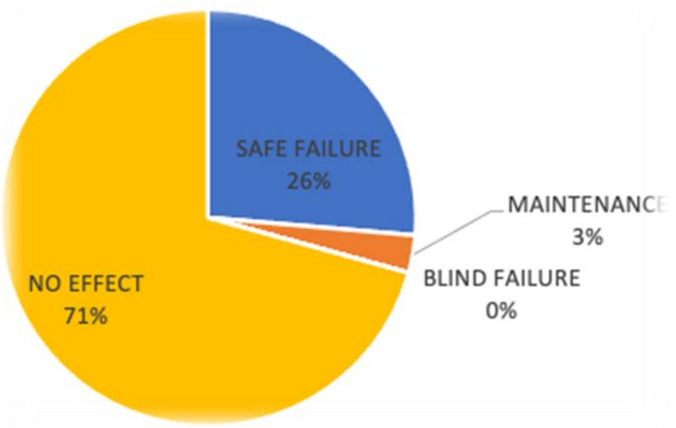
Experts & designers

	Component	Failure mode	Mode failure rate FIT	Expert-assigned end-effect
C1	Capacitor	Drift	19.98	NO EFFECT
C1	Capacitor	Shorted	10	BEAM DUMP
			…	
D1	Diode	Shorted	4.57	NO EFFECT
			…	

- Designers assigning **end-effect** for the entire system **to each failure mode** (could be limited to critical parts of the design)

- Followed by a **common review** with designers, experts, reliability team

- **Work-intense element of the study**, requiring deep knowledge of the system
  - ”What is the impact of a component failing one way on the entire board?”
  - As much support as possible provided.



End Effects
Example from another project

Blind failure (single path).	
Blind sync	Not generating asynchronous dump request.
Blind async	Not generating a synchronous dump request.
Blind	Not generating asynchronous nor synchronous dump requests.
Blind failure (both paths)	
Blind both paths sync	Not generating asynchronous dump request on both paths.
Blind both paths async	Not generating a synchronous dump request on both paths.
Blind both paths	Not generating asynchronous nor synchronous dump requests on both paths.
False dumps	
False dump async	Spuriously generate ONLY asynchronous dump request.
False dump sync	Spuriously generate ONLY synchronous dump request.
False dump	Spuriously generate asynchronous and synchronous dump requests.
Maintenance	Failure will cause maintenance action after the mission (LHC fill) is finished.

Conclusions

- **Rotary switches – very high failure rate in 217Plus standard**
  - Establishing non-criticallity of their failures could let us focus on the remaining faults.
- **Next steps:**
  - Failure mode apportionment and end-effects assignment.
  - FMECA Tables are ready for both boards projects.

References

[1] MIL-HDBK-338B, US Department of Defence, 1 October 1998, https://www.navsea.navy.mil/Portals/103/Documents/NSWC_Crane/SD-18/Test%20Methods/MILHDBK338B.pdf

[2] Failure Mode/Mechanism Distributions – 2016, Reliability Databook Series, Quanterion Solutions Inc., https://www.quanterion.com/product/tools/failure-mode-mechanism-distributions-fmd-2016/

[3] Table FMD-CB.csv, https://gitlab.cern.ch/mblaszki/fmeca-assist-tool/-/blob/cd5826e15fc053132d3b6e6cfb34f6e50755b08b/resources/FMD-CB.csv

[4] HDBK-217Plus:2015 Notice 1, Quanterion Inc., 15 January 2017, https://www.quanterion.com/products-services/tools/217plus/

[5] Isograph Reliability Workbench, Isograph Ltd., https://www.isograph.com/software/reliability-workbench

[6] Automatizing Component-FMECA Analyses for Electronics Assemblies, Joint RAWG & Electronics Forum Meeting, 11 April 2024, https://indico.cern.ch/event/1398920/

[7] HDBK-217Plus:2015, Quanterion Solutions Inc., 15 December 2014, https://www.quanterion.com/product/publications/hdbk-217plus-2015/

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