

FMECA End-effects

TSU CONS Reliability Study Progress Meetings #7

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End-effects in TSU FMECA

Categories of failure modes' effects in the table

All options assigned to failure modes:

- Unpredictable
- Asynchronous Beam Dump
- Synchronous Beam Dump
- Downtime
- Loss of injection permit
- No diagnostics (RTM only)
- No effects

Less critical



Requirements:

- 1 failure in **1,000 years** (\cong 114 FITS)
- 1 failure in **10 years** (\cong 11,400 FITS)
- 1 failure in **1 year** (\cong 114,000 FITS)
- no requirement
- no requirement

FIT – number of failures in 10^9 hours (\cong 115,000 years)

Combining end-effects between TSUs

TSU1 and TSU2

End-effect TSU 1		End-effect TSU 2		Result
No effect	+	No effect	=	No Effect
Async beam dump	+	Sync beam dump	=	Sync beam dump
Downtime	+	No effect	=	Downtime
Async beam dump	+	No effect	=	Async beam dump
...	

TSU 1 column indicates what happens with the affected board.

TSU 2 shows reaction of the other TSU.

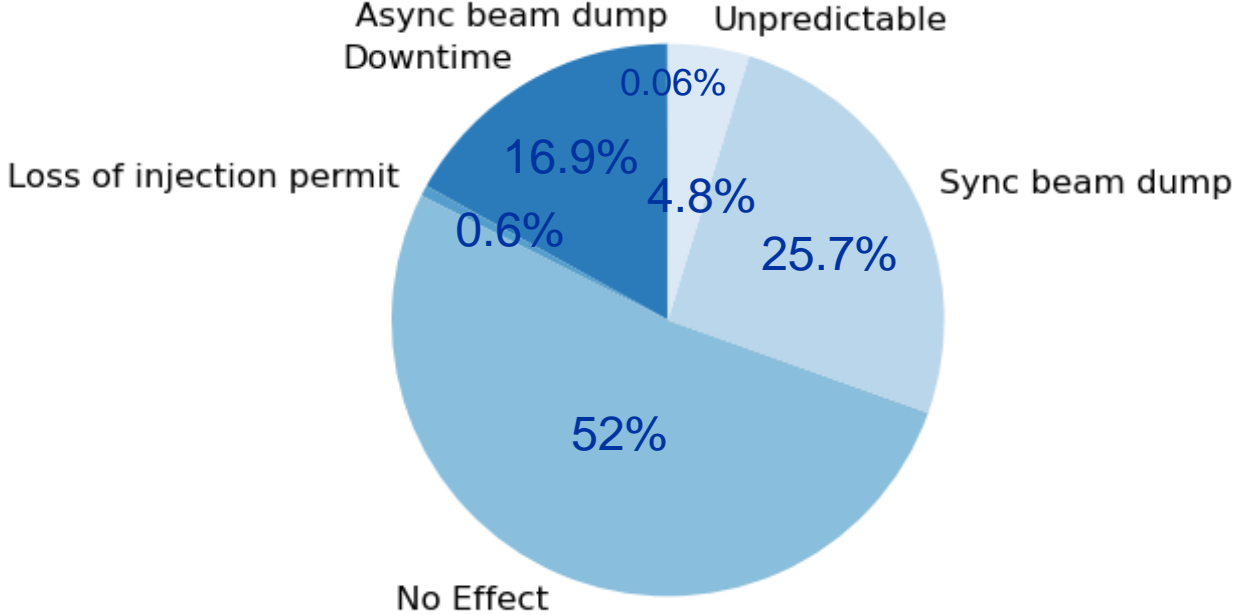
To simplify the analysis, the two columns are **merged together** using rules like shown above.

End-effects identified in TSU FMECA

Breakdown of total FITS

Unpredictable	– 109 FIT
Asynchronous Beam Dump	– 1 FIT
Synchronous Beam Dump	– 594 FIT
Downtime	– 390 FIT
Loss of injection permit	– 14 FIT
<hr/>	
Total (with effects)	– 1,106 FIT
No effect	– 1,202 FIT*

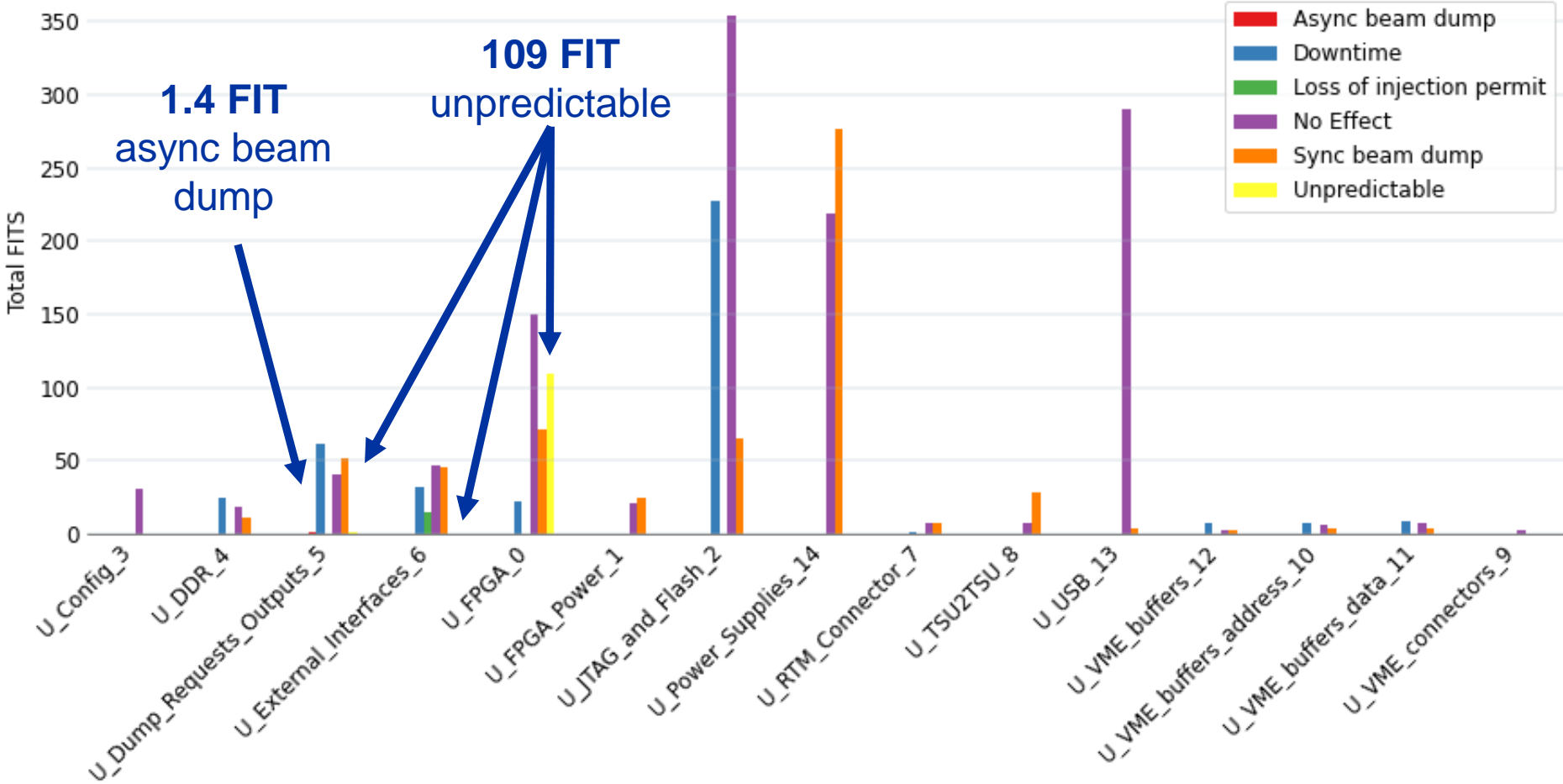
* Without 8 rotary switches (each 8041 FIT according to 217Plus, total – 64,328 FIT)



FIT – number of failures in 10⁹ hours
(≅ 115,000 years)

FITS in TSU design pages

FIT – number of failures in 10^9 hours



TSU End-effect: Unpredictable

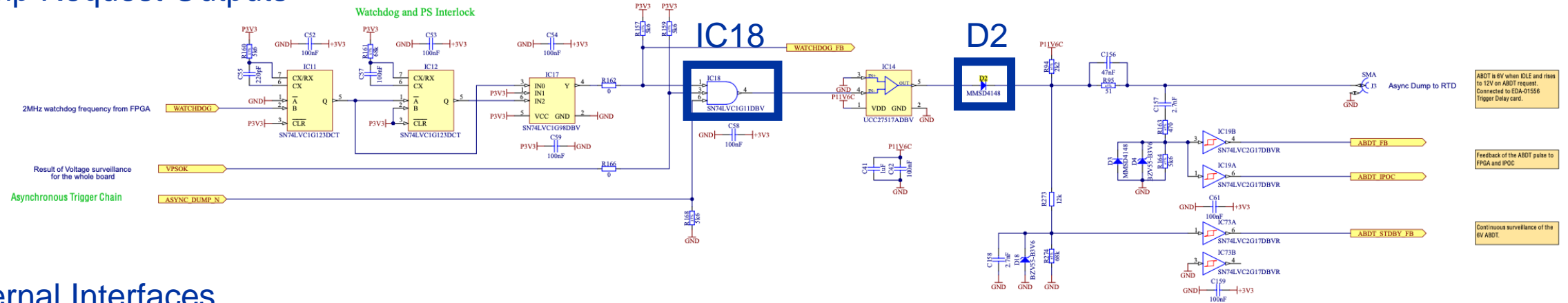
Failure rate: 109 FITS.

Causes:

- **Parameter change** of a switching diode, D2, in *Dump Requests Output*: 2.9 FITS.
- **Parameter change** of an AND gate, IC18, in *Dump Requests Output*: 1.4 FITS.
- **Open, param. change, stuck high/low** of Artix 7 FPGA, IC1: 27 FITS x 4.
 - Exact effect depending on the pin.
- **Parameter change** of the RS-485 Transceiver, IC41, in *External Interfaces*: 1.4 FITS.

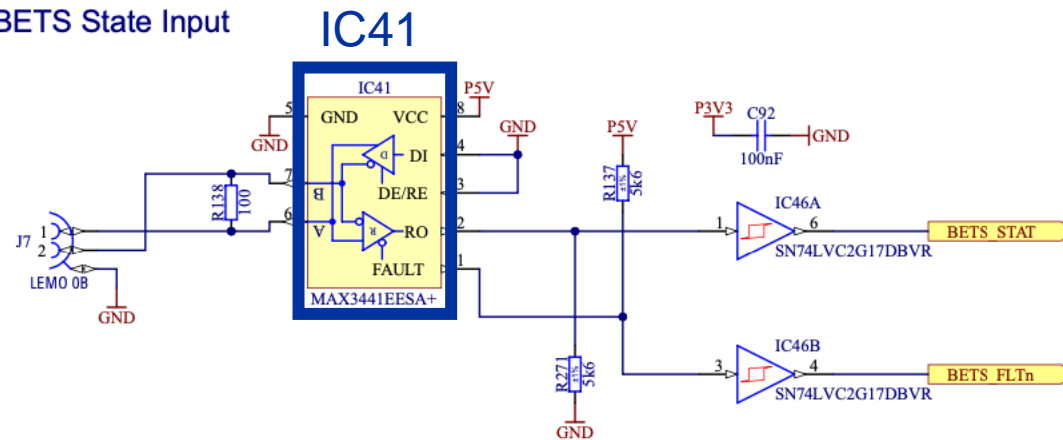
TSU End-effect: Unpredictable Locations

Dump Request Outputs



External Interfaces

BETS State Input



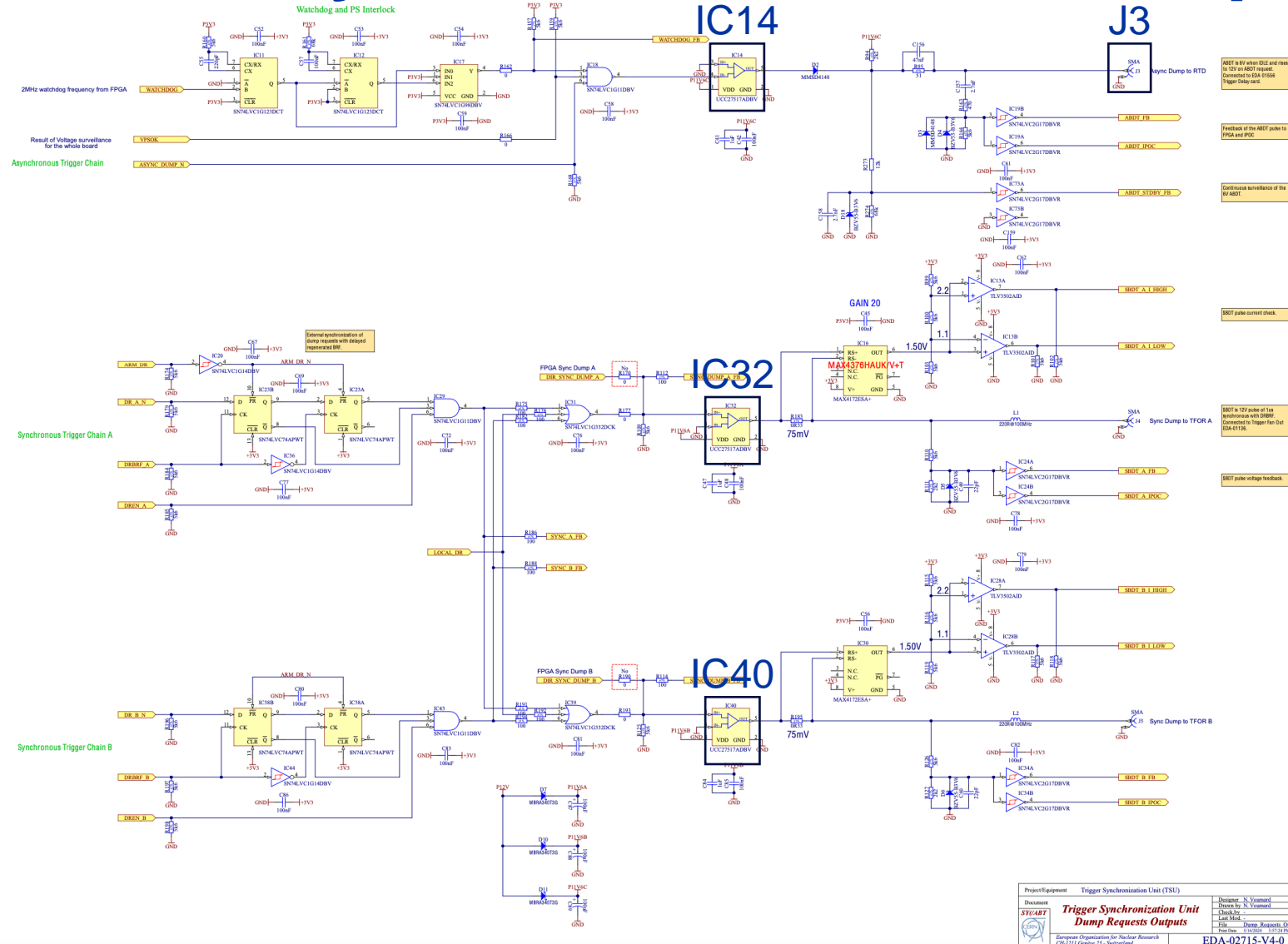
TSU End-effect: Asynchronous Beam Dump

Failure rate: 1.4 FIT.

Causes:

- **Stuck high or parameter change** in gate drivers, IC14, IC32, IC40, in *Dump Requests Outputs*: 0.2 or 0.5 FIT.
- **Open, poor contact/intermittent, short** in PCB Jack, J3, in *Dump Requests Outputs*: 0.2 FIT.

TSU End-effect: Synchronous Beam Dump Locations



Project/Equipment	Trigger Synchronization Unit (TSU)	Designer	N. Vismont	XXXX/XXXX
Document	Trigger Synchronization Unit Dump Requests Outputs	Drawn by	N. Vismont	3/20/2023
SVI/CART		File Name	Trigger_Sync_Unit_Dump_Requests_Outputs	3/20/2023
		File Path	D:\Data_Requests_Outputs_Sch\TSU	3/20/2023
		File Size	1013210	3/20/2023
		File Type	Sheet 1 of 1	3/20/2023
European Organization for Nuclear Research CE-11511 Geminus 23 - Switzerland		EDA-02715-V4-0		

TSU End-effect: Synchronous Beam Dump

Total: 594 FITS.

Top contributors:

- **Short** in temperature monitors, IC6: 56 FITS.
- **Short** in Artix-7 FPGA, IC1: 27 FITS.
- **Failures** in transistors T11, T12: 22 FITS.
- **Failures** of fuses F1, F2, F3: 20 FITS.

Remaining components' failure rates are below 20 FITS.

End-effects identified in TSU RTM FMECA

Breakdown of total FITS

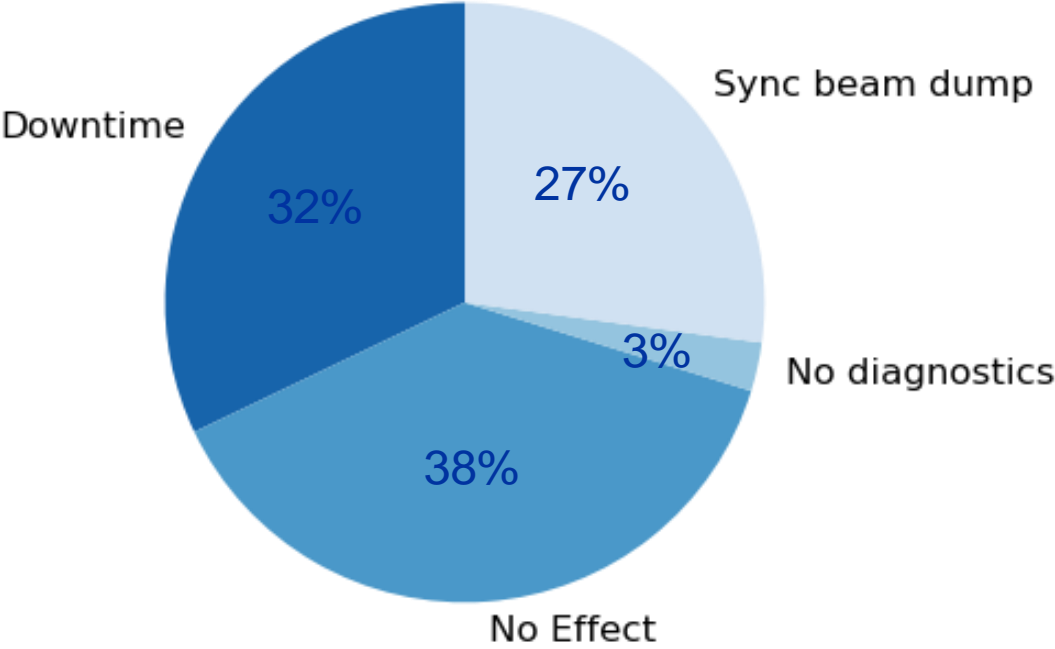
Synchronous Beam Dump – 83 FIT

Downtime – 99 FIT

No diagnostics – 8 FIT

Total (with effects) – 190 FIT

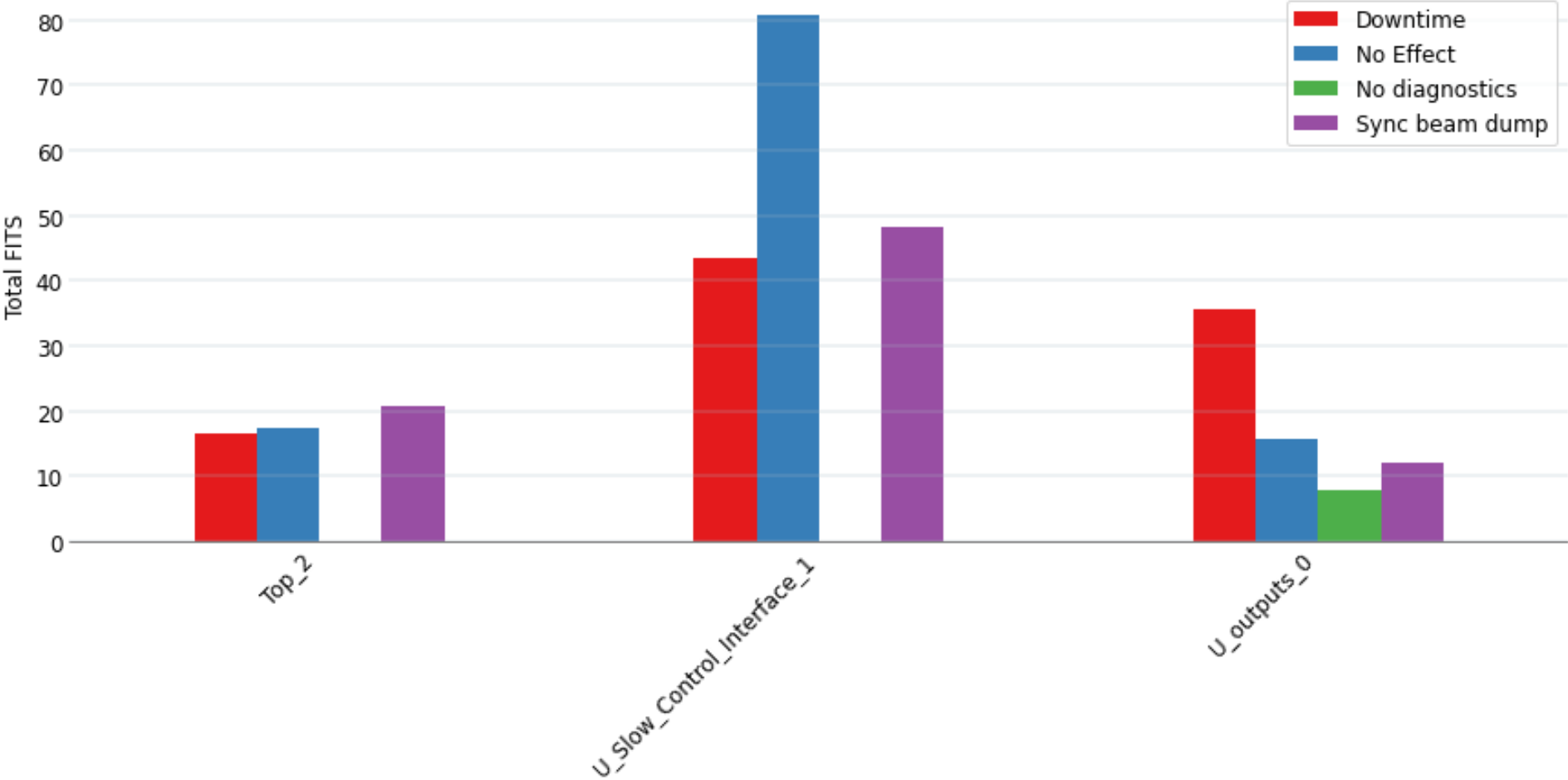
No effect – 118 FIT



FIT – number of failures in 10⁹ hours
(≅ 115,000 years)

FITS in TSU RTM design pages

FIT – number of failures in 10^9 hours

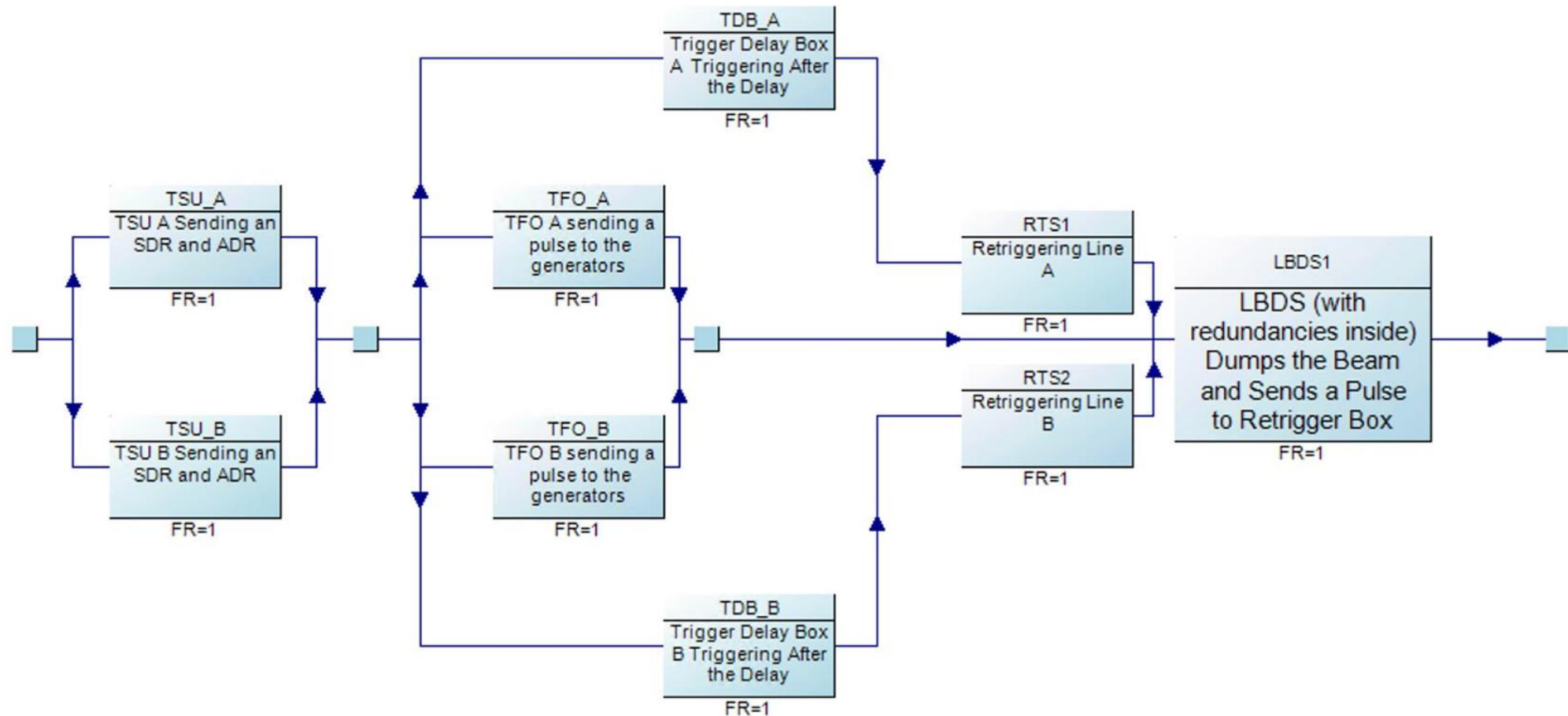


TSU Hybrid MC Model

FMECA inputs for the model

TSU Hybrid MC Model

Asynchronous beam dump not triggered by BIS



Failure rates to be used in the model

Can “no effect” lead to an effect?

Certain failure modes are assigned “no effect” and “no effect” but lead to loss of redundancy.

Example:

- A. **Fuses F4 and [F5], param. change or short:** assigned “no effect”, “no effect”, with comment: “loss of SBDDT1[2] path”.
- B. **Switching diode D2, open:** “no effect”, with comment: “Loss of ABDDT path”.

Can failure modes like this “linger” in the system unnoticed?

- On the other hand, there is “loss of SBDDT1 path” with async dump of a gate driver stuck high – but that one triggers an synchronous beam dump, therefore – it is safe as

Questions and next steps

1. **Can all of the faults in the “unpredictable” end-effects category lead to missed dumps?**
 2. **Rotary switches (high failure rate estimation and past experience):**
 1. Are their faults at the start of operation also not impacting the functionalities of TSU?
 2. Will their faults require follow-ups and card replacements?
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- **Understanding of repair and inspection strategies.**
 - **Hybrid MC model for missing a beam dump (1 in 1,000 years) when not triggered by the BIS.**



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