Functional Safety Special Interest Group (FS-SIG)
FS-SIG Briefing Note
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SPECIFYING SIF RESPONSE TIME

The commonly cited 'rule of thumb' for SIF response time (SRT) is that it should be less than 50% of the process safety time (PST). It seems this is a judgement on what is an appropriate degree of conservatism to provide confidence that PST will not be exceeded. But the question then arises, on what may this judgement be based?

[I here use the term PST to mean the time from SIF trip point to hazard consequence being realised. NOT the time from initiating event (which may be indeterminate) to hazard consequence being realised.]

We may refine the approach with further consideration of what a design margin between SRT and PST represents. It represents the possible growth in SRT that may be tolerated without the PST being exceeded within the mission time for the SIF.

The concern then is with **how quickly** the SRT may degrade if it should begin to slow because of **systematic** operational influences. These would typically be due to fouling effects causing valves to stick or for sensor response time constants to grow. But note that response time may also grow from valve seal/gland degradation even on non-fouling duties. (**Random** failures causing violation of the PST limit are addressed by managing the PFD.)

Of course, if the SIF is known to be susceptible to fouling, this systematic failure potential should be addressed as far as is practicable by appropriate design provisions. If complete elimination of SRT growth (other than due to random failure effects) is not practicable, then some allowance needs to be made in the design and testing provisions.

We need confidence that the residual effects will not degrade response time to the point of a SIF dangerous failure before the mission time has expired (after which the SIF should be returned to the 'as new' condition. If there is no expectation of significant response time growth, the margin may be correspondingly narrow. (A tuning fork sensor de-energising a pump motor contactor would be unlikely to be susceptible to response time growth. A thermowell and an actuated valve on a fouling duty would be more of a concern.)

As a systematic defence, the design SRT should be such that even after response time growth during the SIF mission time the PST is not exceeded.

Note that SRT growth is not necessarily linear with time; doubling of the elapsed time does not necessarily mean that growth will simply double; it may be that the growth accelerates/decelerates. If growth is compounded, it may be modelled with the exponential function.

So, if a linear model is adopted, for any given subsystem 'SS' the response time (RT) at expiry of mission time will be:

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$$RT_{SS@MT_{SS}} = T_{SS} \cdot \left(1 + \frac{G_{SS}}{100} \cdot MT_{SS}\right)$$

If an exponential model is adopted, the response time at expiry of mission time will be:

$$RT_{SS@MT_{SS}} = T_{SS} \cdot e^{\left[\frac{G_{SS} \cdot MT_{SS}}{100}\right]}$$

Regardless of the model used or the actual growth mechanisms, the design requirement is that:

$$\{RT_{S@MT_S} + RT_{L@MT_L} + RT_{FE@MT_{FE}}\} < (PST - PTD)$$

PST - Process Safety Time.

PTD – Potential Trip Delay (due to trip setting tolerance).

G_{SS} – Anticipated %response time growth per year for given subsystem

T_{SS} – Anticipated **design** response time when new for given subsystem

MT_{SS} – Mission Time for given subsystem (Years.)

RT_{SS} – Response Time for given subsystem

Specific subsystem designated by subscript:

S – sensor, L – logic solver, FE – final element

Different design options may be evaluated for suitable design SIF response time using these formulae. If the design SRT at MT expiry is found to exceed (PST-PTD), a faster design is required, or one that is less susceptible to response time growth, or the mission time reduced, or some combination of these possibilities.

Once actual SRT for new healthy SIF are identified at validation, the corresponding ‘as-installed’ values for T may be substituted into the above equation to identify the anticipated full growth values. During proof testing, the prevailing response performance of individual subsystems or of the complete SIF, may then be checked against these full growth (end of mission time) values. If found to exceed these values before expiry of mission time, rectification works must be implemented and appropriate revisions to the design or the mission time(s) made. (It would be perverse to use the longer anticipated design response time specification when a healthy SIF performs faster.)

Clearly, this approach to SRT specification is not an exact science, (because of the uncertainty in G and growth mechanisms), but it does provide a more discriminating enhancement over the somewhat

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arbitrary 50% rule. (The 50% rule takes no account of mission time or the nature of the design and its application. It is equivalent to 7% per year exponential growth across a 10-year mission time, or 10% linear growth.)

Design SRT/PST	Mission Time (years)					
	5		10		20	
	Exp.	Lin.	Exp.	Lin.	Exp.	Lin.
50%	14	20	6.9	10	3.5	5
75%	5.8	6.6	2.9	3.3	1.4	1.7
90%	2.1	2.2	1.1	1.1	0.5	0.6
95%	1	1	0.5	0.5	0.3	0.3

Table 1: Annual Growth Percentages (G_{SS}) Corresponding with Design Margin and Mission Time.

It can be seen that at lower values of growth percentage there is little difference between exponential and linear growth over the typical mission time periods. (As with Probability of Failure on Demand (PFD), over suitably small intervals, a straight line approximation to the exponential curve may be used.) For a given value of G_{SS} an assumption of exponential growth will be more conservative. I speculate that exponential growth may better represent biological fouling or progressive loss of mechanical clearances?

G_{SS}	Mission Time (years)					
	5		10		20	
	Exp.	Lin.	Exp.	Lin.	Exp.	Lin.
1%	1.05	1.05	1.1	1.1	1.22	1.2
2%	1.1	1.1	1.22	1.2	1.49	1.4
5%	1.28	1.25	1.65	1.5	2.7	2
10%	1.65	1.5	2.7	2	7.4	3

Table 2: Growth Factors Across Mission Time

If duty specific degradation mechanisms are anticipated to impact significantly on response time, a judgement will need be made about expected growth over the proposed mission time. (It may be the consideration that dictates mission time.) Wherever possible this judgement should be informed by experience. A preliminary estimate may be made, with more frequent tests undertaken to investigate actual growth in service, with the test interval progressively increasing up to that required by $PFD_{average}$ considerations. Perhaps with a nominal doubling, e.g., after 3 months, 6 months, 12 months.

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If higher growth than anticipated is experienced, the corresponding adjustment may be made to the estimate for G, the mission time, the growth model, or the design revised as appropriate. Using the exponential model and with elapsed time from new (ET) in years:

$$Observed\ G_{SS} = \frac{\ln\left(\frac{SRT_2}{SRT_1}\right)}{(ET_2 - ET_1)} \times 100\%$$

Using a linear model:

$$Observed\ G_{SS} = \frac{(SRT_2 - SRT_1)}{(ET_2 - ET_1) \times SRT_{new}} \times 100\%$$

The 7% exponential/10% linear, which corresponds with the 50% rule of thumb across a 10 year mission time, appears disconcertingly high. If 10% exponential, growth would be by a factor 2.7. If a SIF was expected to suffer this level of response time growth it would invite questions about the systematic susceptibilities of the design. We might then take this as representing the upper end of practically acceptable values.

At the lower end, for SIF that are positively identified as NOT susceptible to response time growth, we might take a value for G_{SS} of 0.5%. **For want of anything better**, the following are suggested as suitable values to provide an appropriate margin. Users should adopt values informed by experience whenever possible.

Subsystem Characteristics	G_{SS}
No significant growth expected. Typically, logic and electrical FE. Sensor not susceptible to process conditions.	0.5%
Clean duty sensors and actuated valves. Significant growth not expected but some potential from stem/seal frictional effects or sensor response susceptibility to process conditions.	2%
Potential for growth through e.g., crystallisation, drop out, deposition, biological growth, elastomeric seal swelling, corrosion, etc.	Informed by experience or test programme. Otherwise, initial default 7% (Exp.) 10% (Lin.)

Table 3: Suggested Values for Growth Percentages

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Note that there is no expectation that these figures will accurately predict growth, it is rather a question of identifying an appropriate **maximum** design response time specification for SIF response speed, in recognition of the mission time, the nature of the equipment, and the duty it is deployed to. For many applications there may be no difficulty in providing a design that is much faster than this specification, particularly when using electrical FE. However, there are those applications where unduly conservative specifications may cause unwarranted difficulties with the design.

Note that the first design effort should be towards eliminating the potential for systematic failures and in correcting any that are discovered.

(This note derived from the addendum to Functional Safety in Practice, 4th Ed., Harvey T. Dearden, 2022. Available from Amazon.)