BASTION TECHNOLOGIES

Two Is One, One Is None: A Discussion on Redundancy

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Objective

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"Goldilocks" situations of redundancy:

- Too Little – Single points of failure.
- Too Much – More doesn't mean better.
- Just Right – The "Best" amount of redundancy

Concepts

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- In engineering, redundancy is the duplication of critical components or functions of a system with the intention of increasing reliability of the system, usually in the form of a backup or fail-safe.

- A Single Point of Failure (SPOF) is a part of a system that, if it fails, will stop the entire system from working.

- A Common Cause Failure (CCF) event is a failure where two or more items fail within the mission time from a common failure mechanism.

“Too Little”

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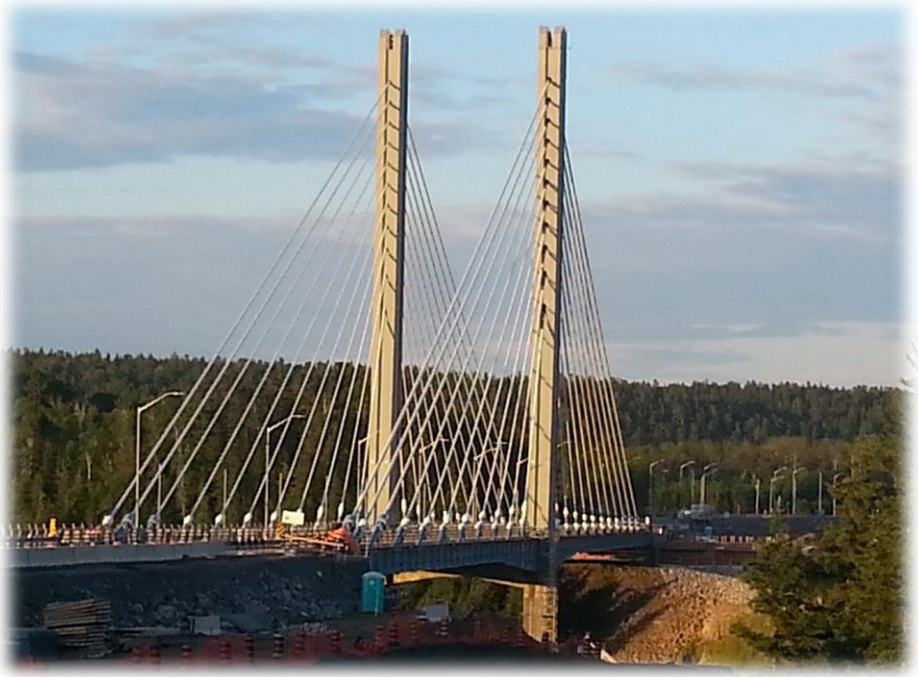
The 2016 Nipigon River Bridge Closure



“Too Little”

The 2016 Nipigon River Bridge Closure

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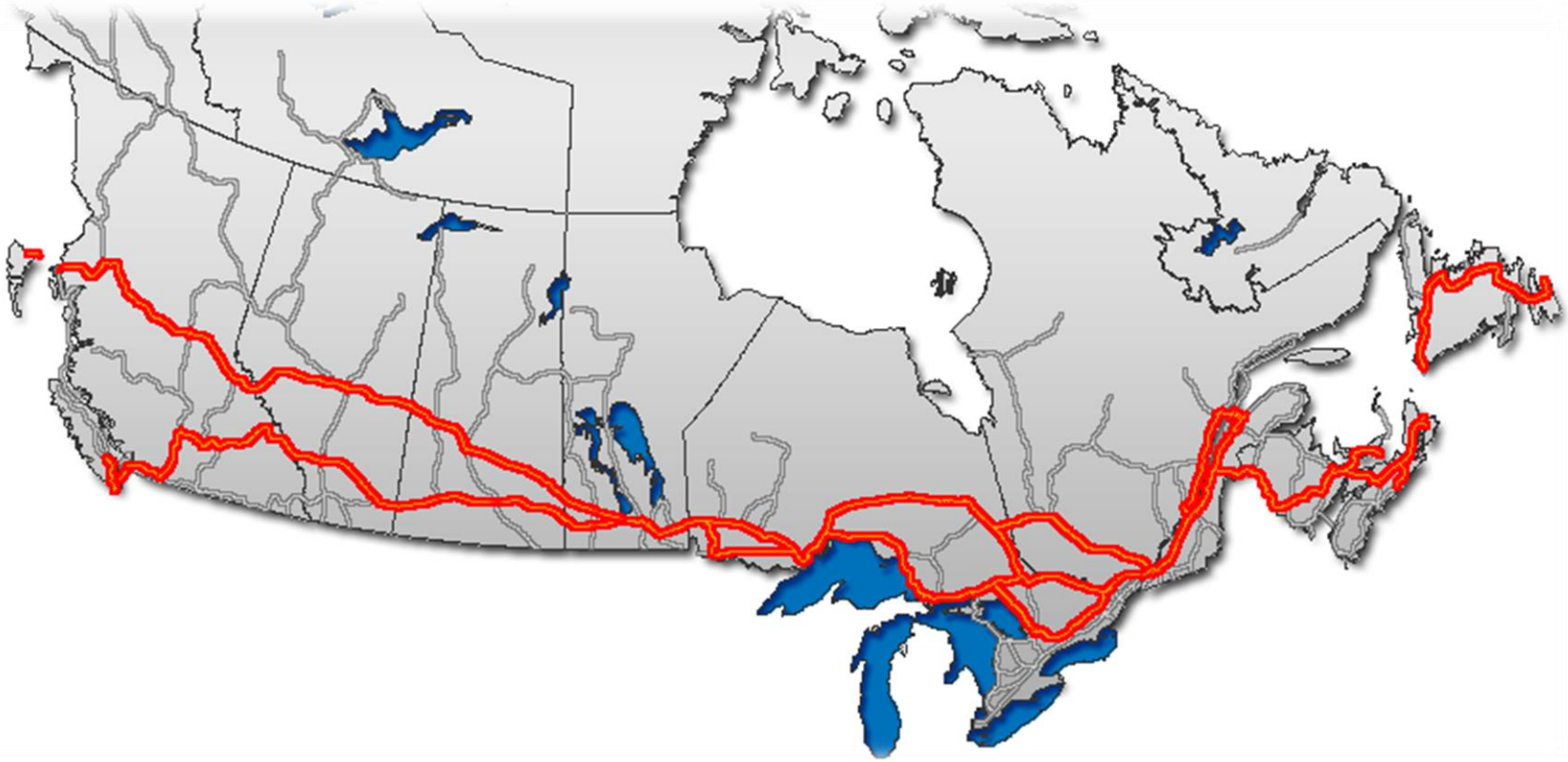
The Trans-Canada Highway



“Too Little”

The 2016 Nipigon River Bridge Closure (cont.)

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The Trans-Canada Highway

"Too Little"

The 2016 Nipigon River Bridge Closure (cont.)

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- Received winter damage January 2016, resulting in indefinite closure of the bridge.
- All road traffic stopped for 17 hours, until a single lane was reopened and used for alternating traffic between directions.
- As of the next day, 15-20 minute wait to cross single-lane.
- Estimated for that day over $100 million of goods within Canada delivered by truck were delayed by this closure.

“Too Little”

The 2016 Nipigon River Bridge Closure (cont.)

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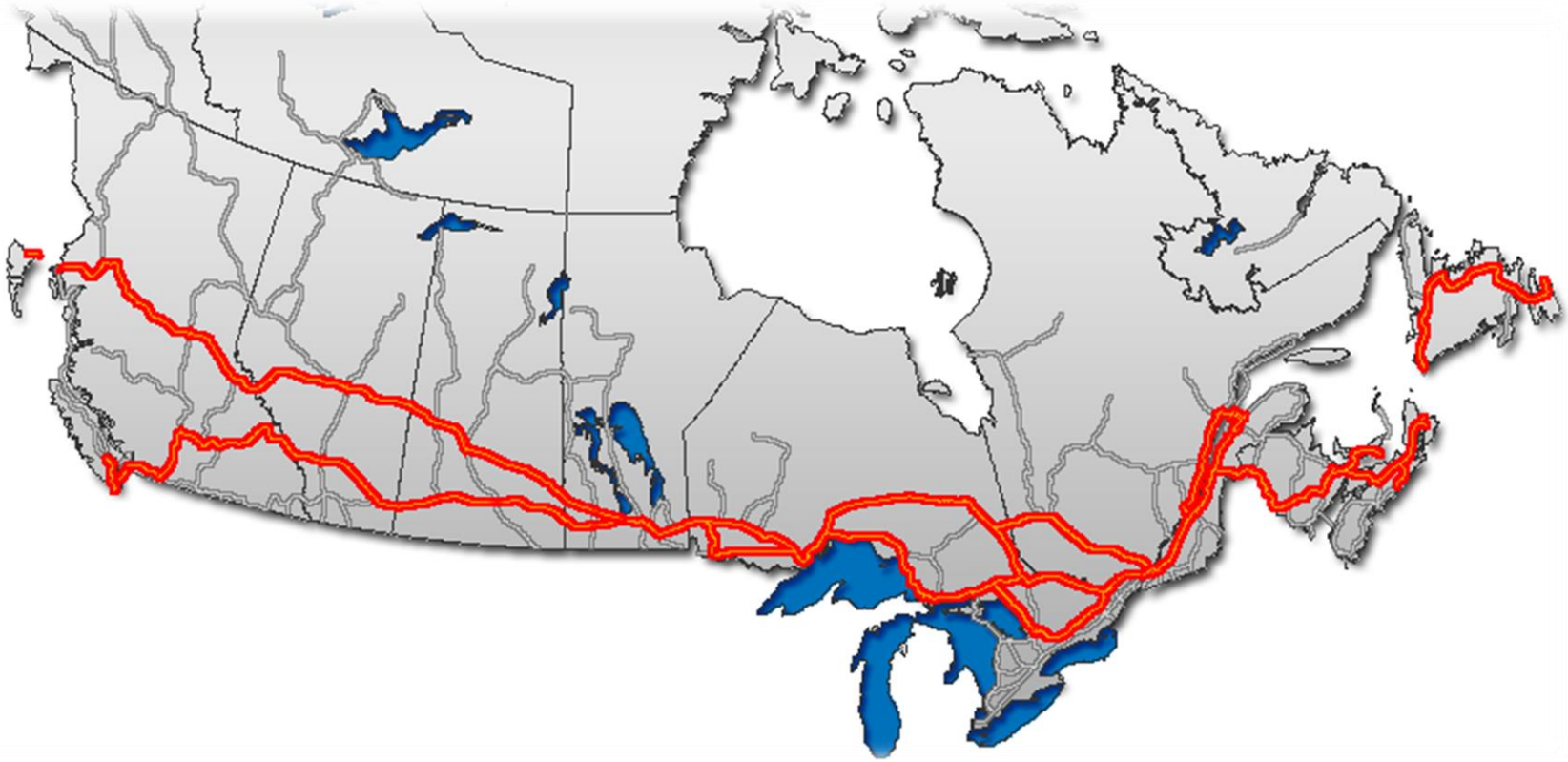
The Trans-Canada Highway



“Too Much”

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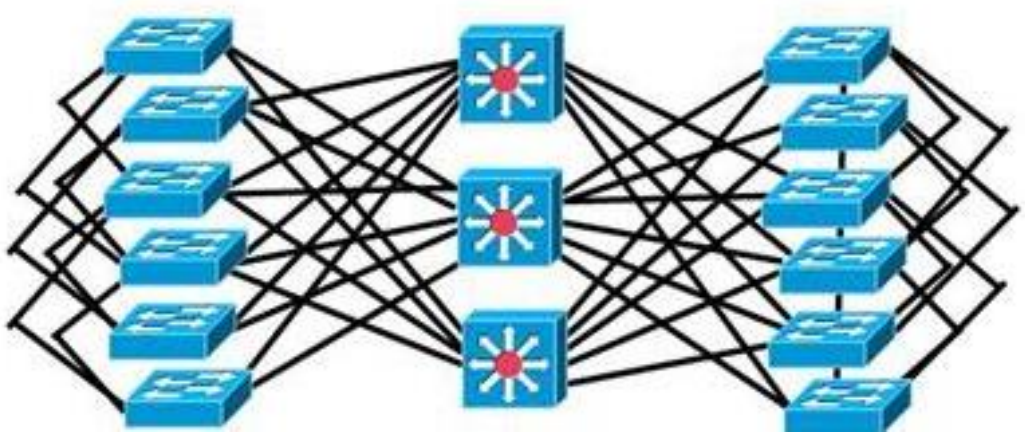
Additional Redundant
Trains of Communications
on Space Vehicles



“Too Much”

Additional Redundant Trains of Communications

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- From an outsider’s perspective, adding redundant trains into a system would increase the reliability of that system by a factor equal to the number of redundant trains, or does it?
- The aerospace industry often has limitations on weight, space, cost, and schedule, so a better understanding of the impact that redundancy has on reliability can result in more appropriate design decisions.
- 2017 RAMS presentation, “How Much Redundancy is too Much Redundancy?” by Adam Harden.

"Too Much"

Additional Redundant Trains of Communications (cont.)

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Analysis utilizing redundant train combinations of communication line system on an imaginary space vehicle:

- A "Success" is any one train succeeds (meets its criteria).
- The reliability and probability of failure (PoF) of each combination will be determined from one up to eight trains.
- Perform comparison of the different combinations to demonstrate the returns on reliability.

"Too Much"

Additional Redundant Trains of Communications (cont.)

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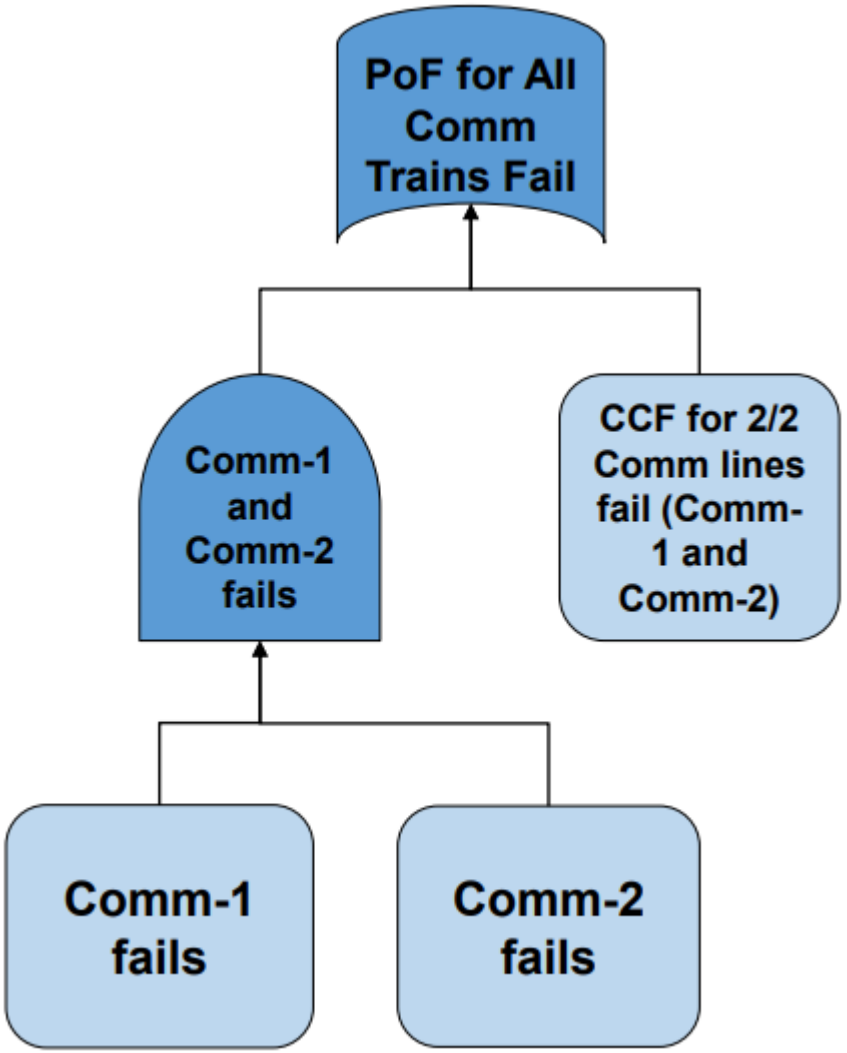
- The fault tree to the right presents the logic for failure of comm-1 and comm-2
- The PoF for the top gate is:
  - Common Cause Failure (CCF) for 2 of 2 Comm lines, OR
  - Comm-1 AND Comm-2 fail
- For this example, the CCF probability is the product of the independent failure probability and the alpha factor for the failure combination 2 of 2 for generic rate based events
- Similar logic is used to incorporate additional trains



"Too Much"

Additional Redundant Trains of Communications (cont.)

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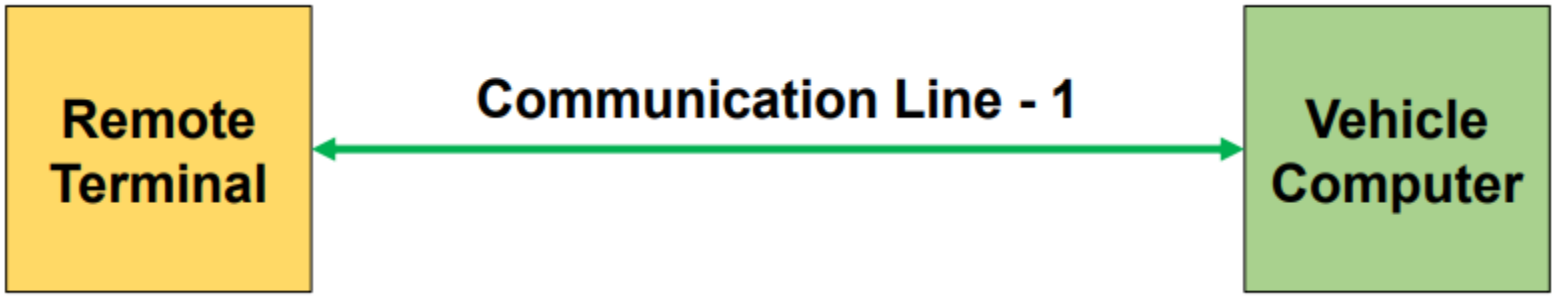
- The below diagram shows a 1-train line system that communicates data between a space vehicle's computer and a remote terminal connected directly to it.



- The table below presents the estimated reliability and Probability of Failure (PoF) of the communication line.

Success Criteria	Reliability	Failure Criteria	PoF
1 of 1	0.999	1 of 1	1.00E-3 (1 in 1,000)

"Too Much"

Additional Redundant Trains of Communications (cont.)

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Success Criteria	Reliability	Failure Criteria	PoF	% Change in Reliability from a Single Train	% Change in Reliability from Each Additional Train
1 of 1	0.999	1 of 1	1.00E-03 (1 in 1,000)	NA	NA
1 of 2	0.99993	2 of 2	6.98E-05 (1 in 14,300)	93.0%	93.0%
1 of 3	0.999959	3 of 3	4.12E-05 (1 in 24,300)	95.9%	2.9%
1 of 4	0.999975	4 of 4	2.52E-05 (1 in 39,700)	97.5%	1.6%
1 of 5	0.999983	5 of 5	1.68E-05 (1 in 59,500)	98.3%	0.8%
1 of 6	0.999987	6 of 6	1.30E-05 (1 in 76,900)	98.7%	0.4%
1 of 7	0.999993	7 of 7	7.17E-06 (1 in 139,400)	99.3%	0.6%
1 of 8	0.999996	8 of 8	4.29E-06 (1 in 233,200)	99.6%	0.3%

Largest increase in reliability comes from the addition of a second train. Note that the percent change in reliability from each additional train is reduced at each interval, except from a group size of 6 to 7.

“Just Right”

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The “Best” Amount

Of Redundancy

“Just Right?”

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- The “Best” amount of redundancy is always evolving.
- Time - Infrastructure and systems built decades ago were sufficient at the time but with aging comes degradation of effectiveness.
- Costs – A safety feature from decades ago would be too costly or bulky to make standard before, can now fit in a fraction of the space and at a fraction of the cost.
- The “Human Element” – Navigate the waters.
- “Make” the “Best” of it.

“Just Right?” (cont.)

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Conclusion

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- Too Little – Infrastructure that relies heavily on truck deliveries without alternate transit points can lead to disaster.

- Too Much – Adding significant redundancy does not necessarily mean significant increases to reliability.

- Just Right? - Find the sweet spot.

Questions?

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Backup Chart "Too Much"

Additional Redundant Trains of Communications (cont.)

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- The table below presents the calculated Alpha Factor values, of specific failure combinations, for generic rate based events

Group Size	Success Criteria	Failure Criteria	Alpha Factor
2	1 of 2	2 of 2	6.88E-02
3	1 of 3	3 of 3	4.12E-02
4	1 of 4	4 of 4	2.52E-02
5	1 of 5	5 of 5	1.68E-02
6	1 of 6	6 of 6	1.30E-02
7	1 of 7	7 of 7	7.17E-03
8	1 of 8	8 of 8	4.29E-03

Backup Charts (Cont'd)

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BIBLIOGRAPHY

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Chart 4 –
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Chart 5 & 6 –
https://en.wikipedia.org/wiki/Trans-Canada_Highway
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Chart 7 –
https://en.wikipedia.org/wiki/Nipigon_River_Bridge
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Chart 8 –
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Chart 9 –
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Chart 10 to 14 –
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Chart 16 -
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Chart 17 -
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