



Is it ready?
Quantifying the maturity of emerging technologies

Charles Rea, DEng, and John Kamp, DEng
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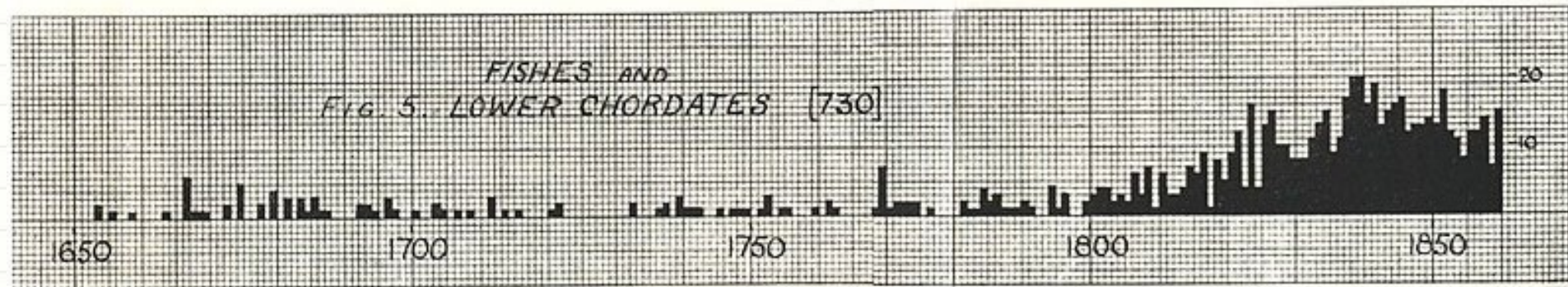
Technology Readiness Assessments

- Establish the technological maturity level of emergent technologies
 - Often rely upon subjective evaluations that
 - depend upon measures *indirectly* associated with
 - the *actual* readiness of a technology for *use in a specific end-use* application
-
- Measuring the readiness of an emerging advanced technology for use in a new system remains *subjective and a source of early program cost and schedule risk*



Bibliometric-based methods

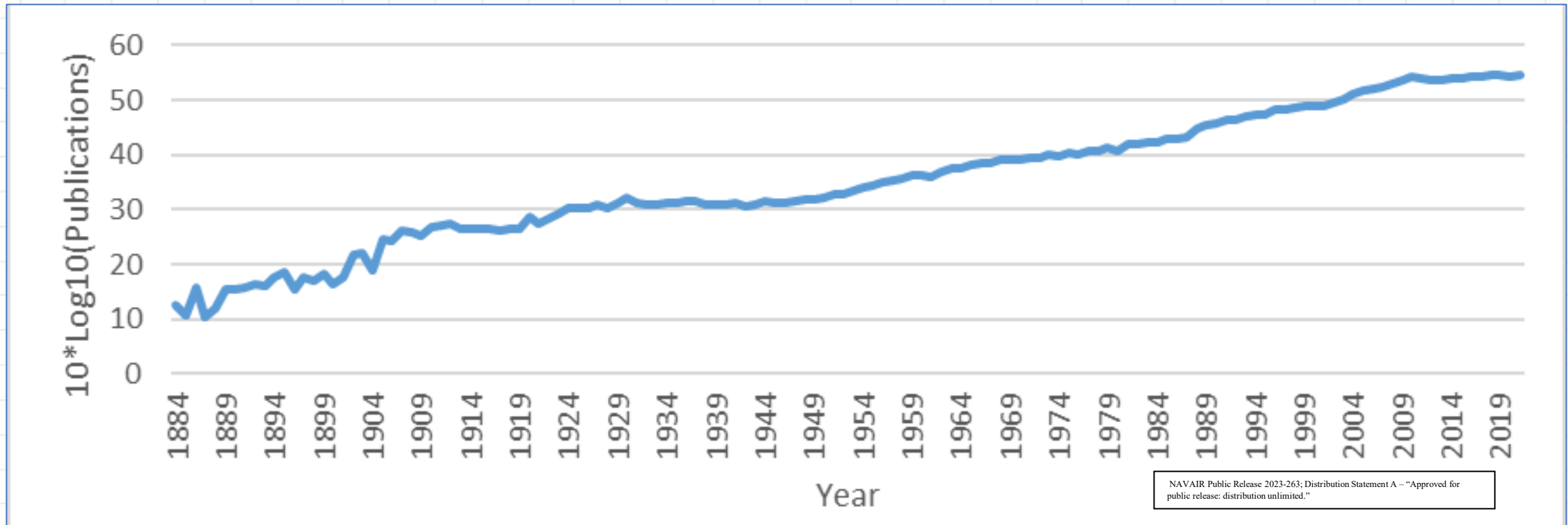
- Sensitive to the search logic, keywords, and the specific corpus used
- Visualization tools and larger datasets provide insights into the overall body of work and identify new patterns and associations



Example publication count over time (Public domain)

- Such methods have not been validated against independent assessments of actual maturity

IEEE publications over time (dB scale)



- 10 dB rise in publications ~ 10x increase in publications
- Noisy; denoised by a moving average



A new term: Relative research volume

- *Use research publication data as an objective indication of technology maturity*
- Rise and fall over time indicates the level of technological maturity
- Collected using keyword search on technical databases, such as IEEE Explore, over time on a yearly basis

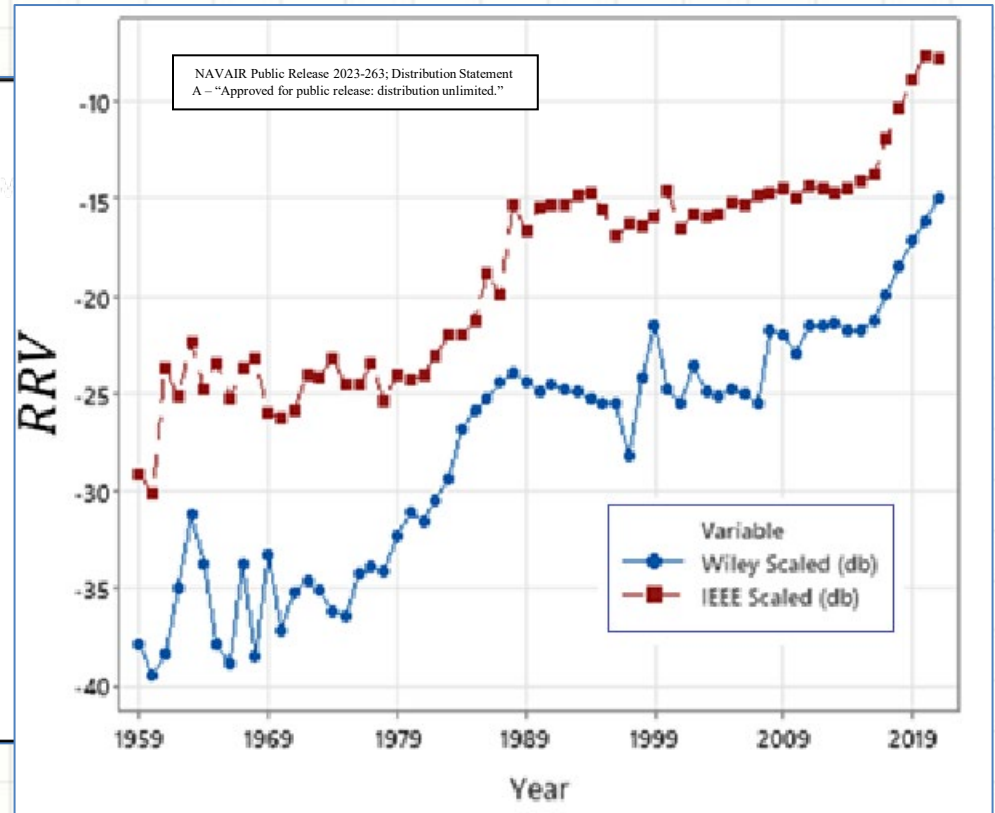
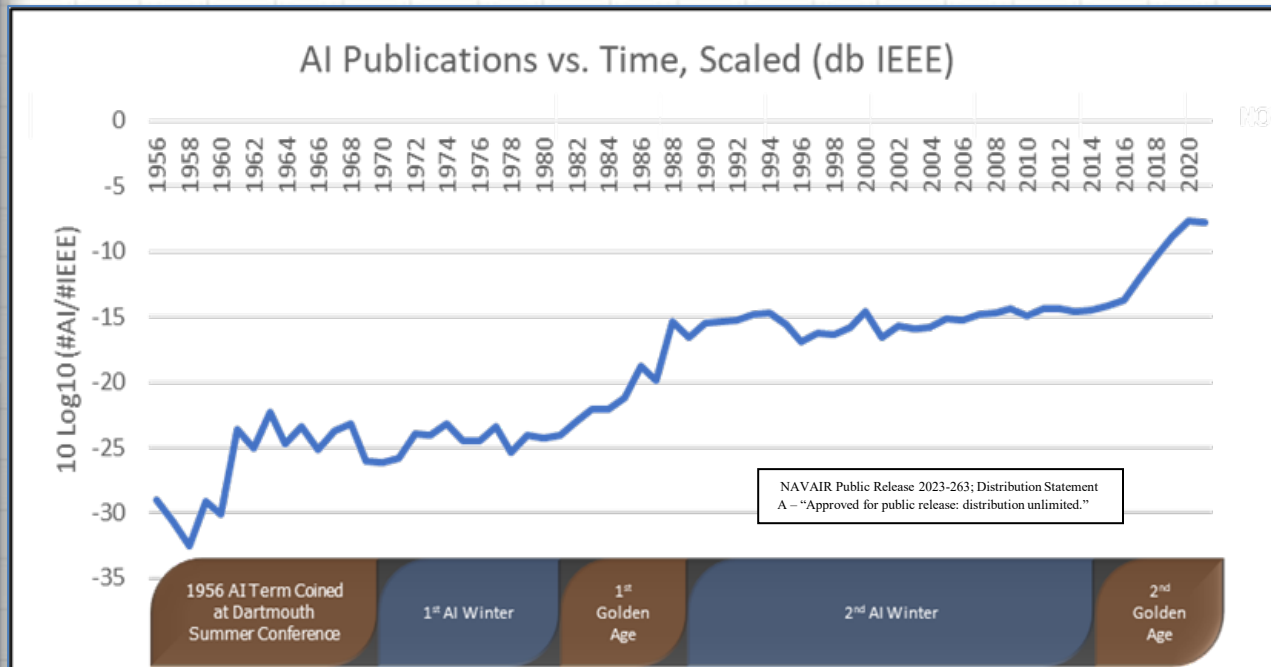
$$RRV_n = 10 \log_{10} \left(\frac{T_n}{R_n} \right)$$

- T_n - total publications for a specific search term (in repository n) in a year
- R_n - total publications count in repository n in the same year



Topic-specific relative research volume (RRV)

Topic- specific RRV – artificial intelligence



Calibrating RRV

- Used independent technology maturity declarations
 - 2003-2021 GAO Defense Acquisitions Assessments of Select Weapon Program reports
- Yes (mature)
 - program IOC
 - GAO declaration of Yes, or
 - replacement with a mature substitute
- Table - technologies or systems with known technologies
 - corresponding to search terms available in the IEEE or Wiley online repositories

#	Technology	Year	Mature?	Notes
1	F-35 Software Defined Radio	1995	No	Program Start,
		1999	No	1999 JSF SAR Pg 113
		2015	Yes	USMC IOC
2	F-35 Sensor and Data Fusion	1995	No	Program Start
		2015	Yes	USMC IOC
3	F-35 Organic Light Emitting Diode	2019	Yes	Gen III HMDS Fielding
4	F-35 Agile Engineering	2017	Yes	C2D2 (Block 4) start
5	2004 DARPA Grand Challenge - Autonomous Driving	2002	No	Announced in 2002
		2021	No	Current research volume
6	FCS - Network Intrusion Detection	2008	No	GAO Report on FCS
7	FCS - Mobile Ad Hoc Networking	2008	No	GAO Report on FCS
8	FCS - Distributed Fusion Management	2008	No	GAO Report on FCS
9	GAO - Quantum Cryptography	2021	No	GAO Report on Quantum Technol
10	GAO - Quantum Communication	2021	No	GAO Report on Quantum Technol
11	GAO - Quantum Key Distribution	2021	No	GAO Report on Quantum Technol
12	GAO - Quantum Computing	2021	No	GAO Report on Quantum Technol
13	GAO - Quantum Random Number Generation	2021	No	GAO Report on Quantum Technol
14	USPS - Optical Character Recognition	2021	Yes	USPS Deployed OCR
15	CVN 78 Dual Band Radar System	2001	No	2004 GAO Report, CVN-21 Progr
		2021	Yes	CVN 78 IOC
16	E-2D AHE Space Time Adaptive Processing Algorithms	1999	No	2004 GAO Defense Report
		2008	Yes	2008 GAO Defense Report
17	E-2D AHE SiC Power Transistor	2001	No	2004 GAO Report - 2001 program
		2007	Yes	2009 GAO Report
18	GAO - Gait Recognition	2002	No	2002 GAO Report on Biometrics T
		2018	Yes	1st Commercial Availability
19	Space qualified atomic frequency standards	2008	Yes	2008 GAO Page 153
20	MMA Data Fusion	2008	No	2008 GAO Page 157
21	Space Radar - SAR Moving Target Indication	2008	No	2008 GAO Page 167
22	TSAT Program - Dynamic Bandwidth and Resource Allocation	2008	Yes	2008 GAO Page 172
23	VH-71 Voice-over Internet Protocol Security	2008	No	2008 GAO Page 177
24	WGS - Phased Array Radar	2000	Yes	2008 GAO Page 181
25	AMDR - Digital Beamforming	2017	No	2017 GAO Page 98
26	G/ATOR Program - Gallium Nitride Power Amplifier	2016	Yes	2017 GAO Page 108
27	F-22 Geolocation Algorithm	2017	Yes	2017 GAO Page 150
28	F-22 Open Systems Architecture	2020	Yes	2021 GAP Page 130
29	MGUE Anti-Spoof	2017	No	2017 GAO Page 158
30	WSF-M Polarimetric Receiver	2017	No	2017 GAO Page 162
		2019	Yes	2021 GAP Page 114
31	ITEP Additive Manufacturing	2019	No	2019 GAO Page 97



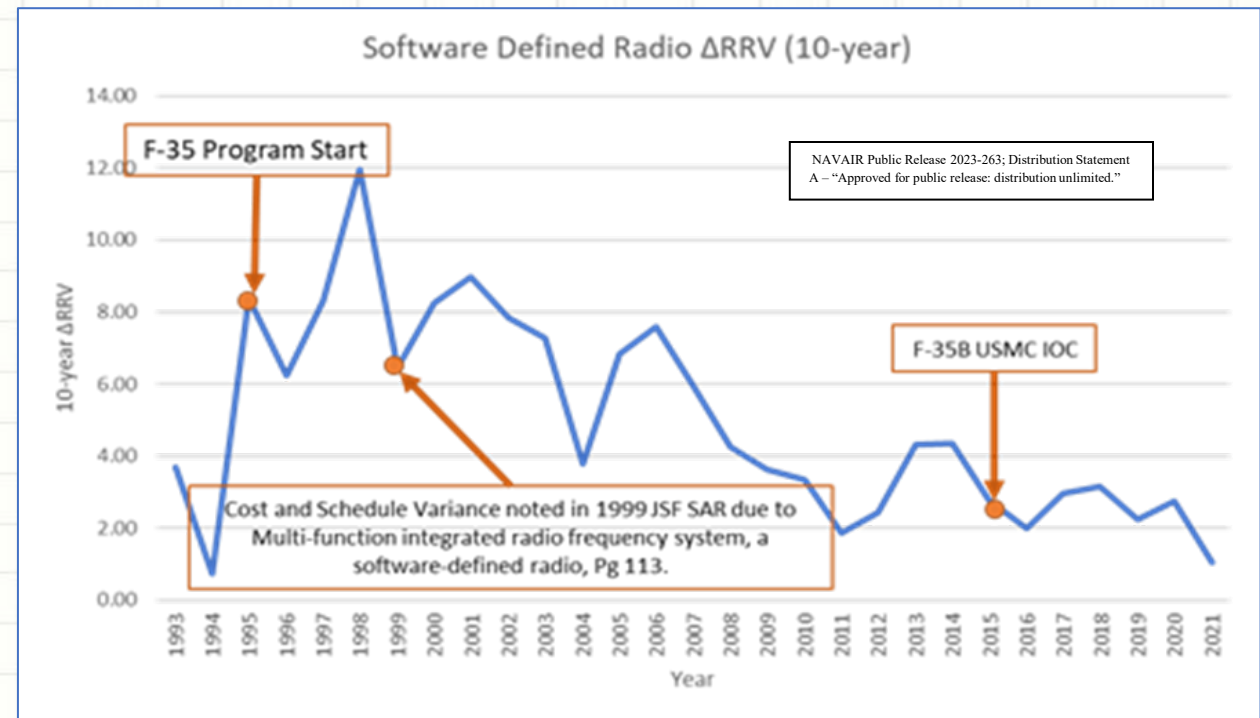
Change in RRV as a maturity measure

- Define the change in relative research volume over time

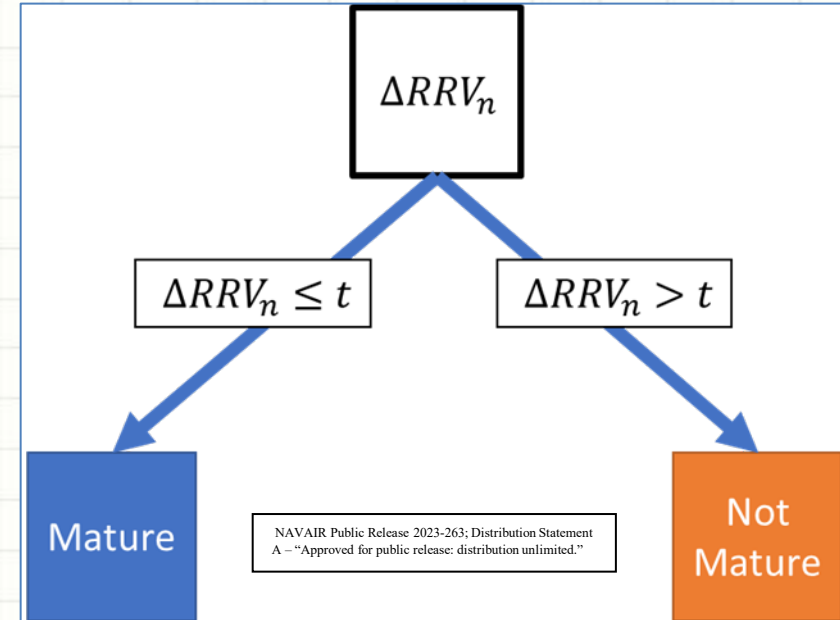
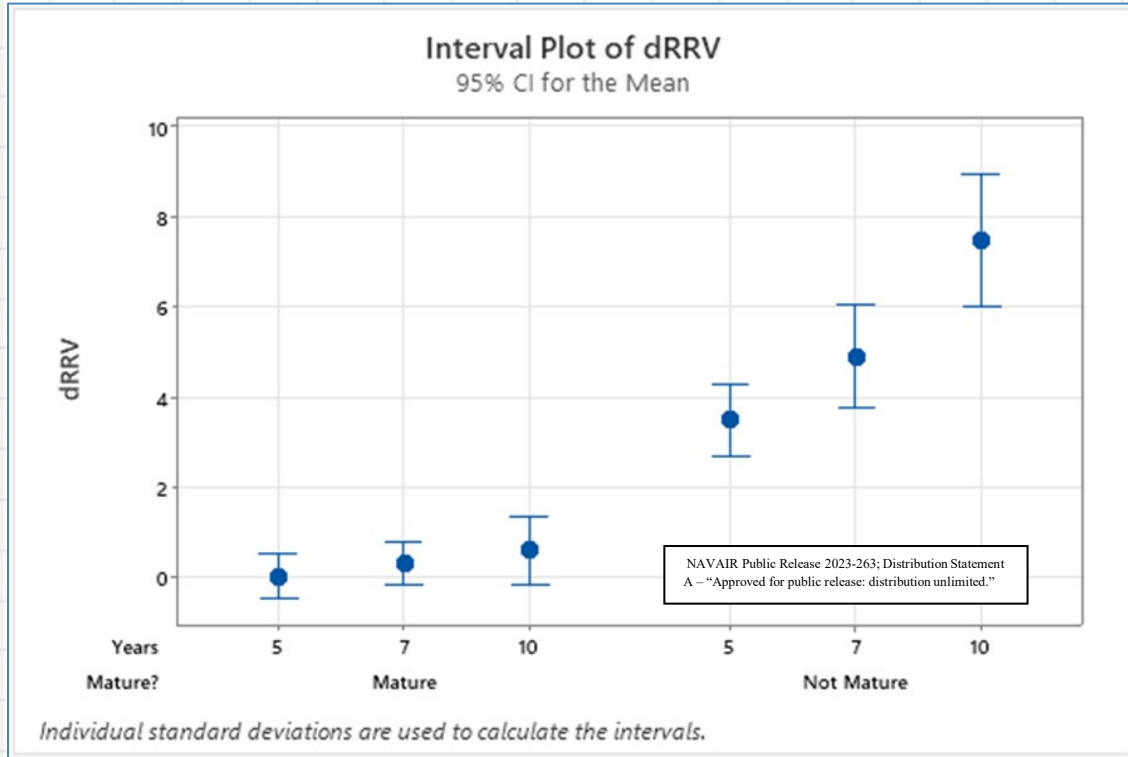
$$\Delta RRV_n = RRV_x - RRV_{x-n-1}$$

- Where x is the year of interest, and n is the length of the moving time average window

ΔRRV_{10} for software defined radio technology



Testing ΔRRV as an indicator of maturity



Conclusions

- Change in relative research volume ΔRRV_n is a relevant measure of technology maturity
 - Enhances ability to get quick looks at technology risk of potential solutions
 - increases insight into critical technology identification, and
 - empowers using the technology maturation planning process
- This research used publicly available data
 - Findings are specific to the analyzed technologies and programs
- The views expressed in written materials or publications, and/or made by speakers, moderators, and presenters, do not necessarily reflect the official policies of the Department of Defense nor does mention of trade names, commercial practices, or organizations imply endorsement by the U.S. Government

