Reliability Improvement Cost Modeling – A Literature Review

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Russ Alexander, PhD, PE
President
SpecTrum A&T Solutions, LLC

SpecTrum Analytical & Technology Solutions, LLC

Problem:

To do optimization, cost-benefit, or break-even analyses for reliability… assumptions are required with regard to the cost of improving system reliability

This brief provides a non-comprehensive overview of available literature of empirical models that explore the relationship between reliability improvements and their related costs

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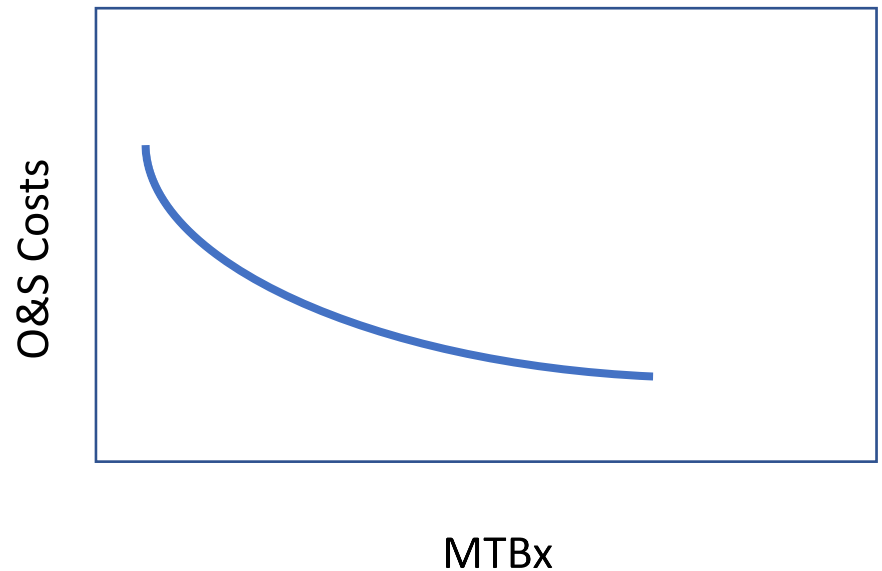

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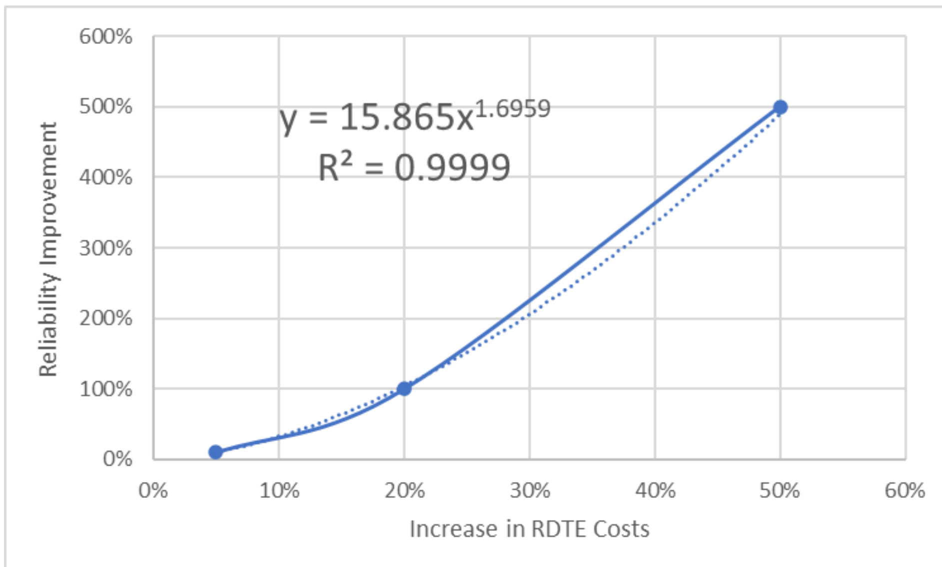
Alexander, Arthur J., "The Cost and Benefits of Reliability in Military Equipment," The RAND Corp., December 1988.



- *Uses data across seven systems: F-18, CH-47D helicopter modernization, F100 turbine engine, Phalanx Mk15 Close-in Weapon System, LAMPS MKIII helicopter antisubmarine warfare system, Minuteman I inertial navigation system, and the Carousel inertial guidance system.*
- *10% increase in reliability adds 5 percent to total RDT&E costs, 100% increase in reliability adds 20 percent to total RDT&E costs, and a 500% increase in reliability would add 50 percent increase in total RDT&E costs*.

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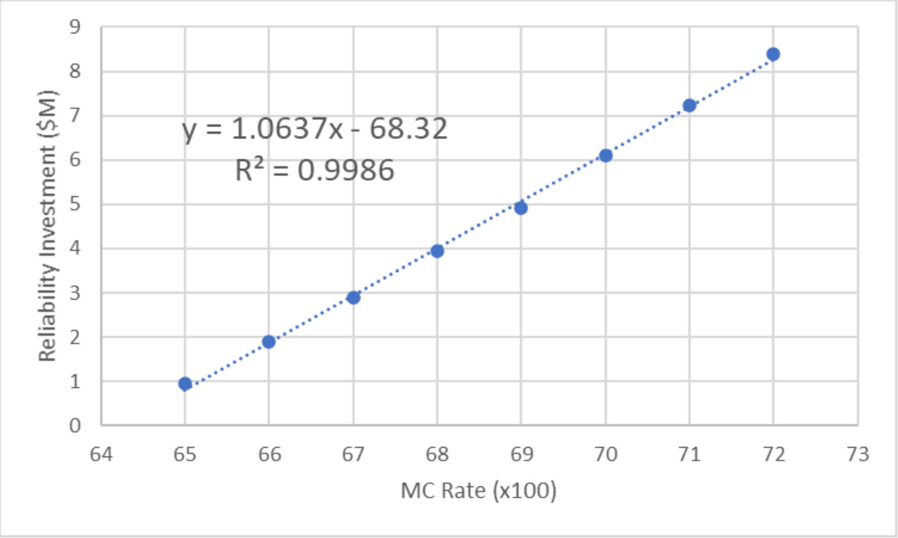
Goldberg, Matthew S. and Tyson, Karen W., "The Costs and Benefits of Aircraft Availability," Institute for Defense Analyses, March 1991.



$$\text{MC Rate} = \frac{(Equipment\ in\ Service\ Hours - Total\ Hours\ not\ Mission\ Capable)}{Equipment\ in\ Service\ Hours}$$

- *Uses data across eleven aircraft models (6 from Navy and Marine Corps, 5 from the Air Force)*
- *Found that MC rates for fleet aircraft are insensitive to development costs prior to IOC but responsive to increases in unit production costs (i.e., most RDT&E dollars are spent on problems other than R&M. R&M problems arising in the field are addressed using procurement dollars)*
- *Found that $1M increase in unit procurement cost is associated with an increase in nearly 1 MC point (reciprocally; the marginal cost for 1 MC point is $1.1M).*

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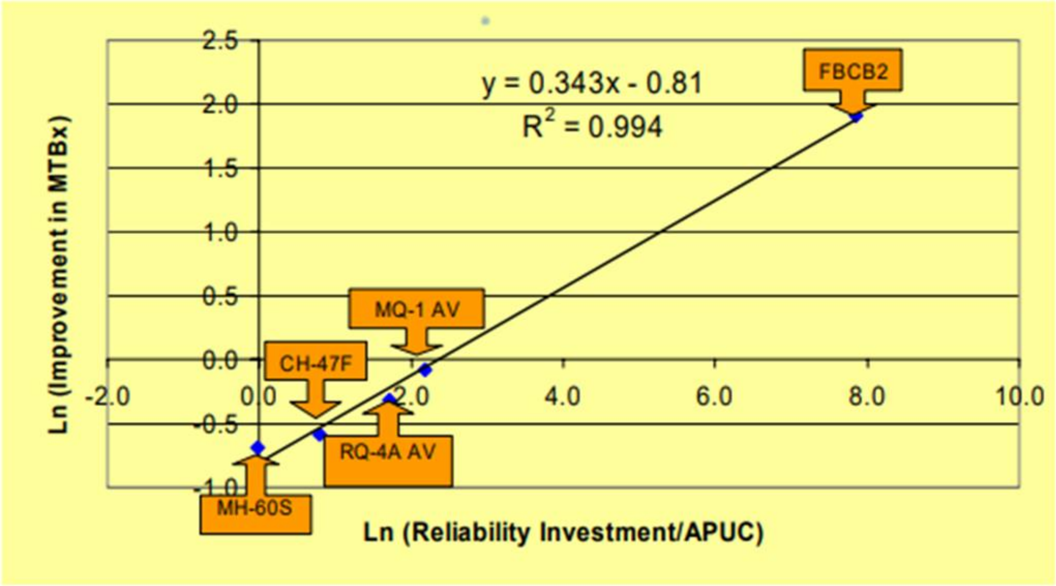
Long, E. A., Forbes, J., Hees, J., and Stouffer, V. "Empirical Relationships Between Reliability Investments and Life-Cycle Support Costs," Report SA701T1, LMI Government Consulting, June 2007.



- *Uses data from 5 systems: MH-60S, RQ-4A AV, CH-47F, MQ-1 AV, and FBC B2 to establish relationship between ln (improvement in MTBx) and ln (Reliability Investment per APUC)*

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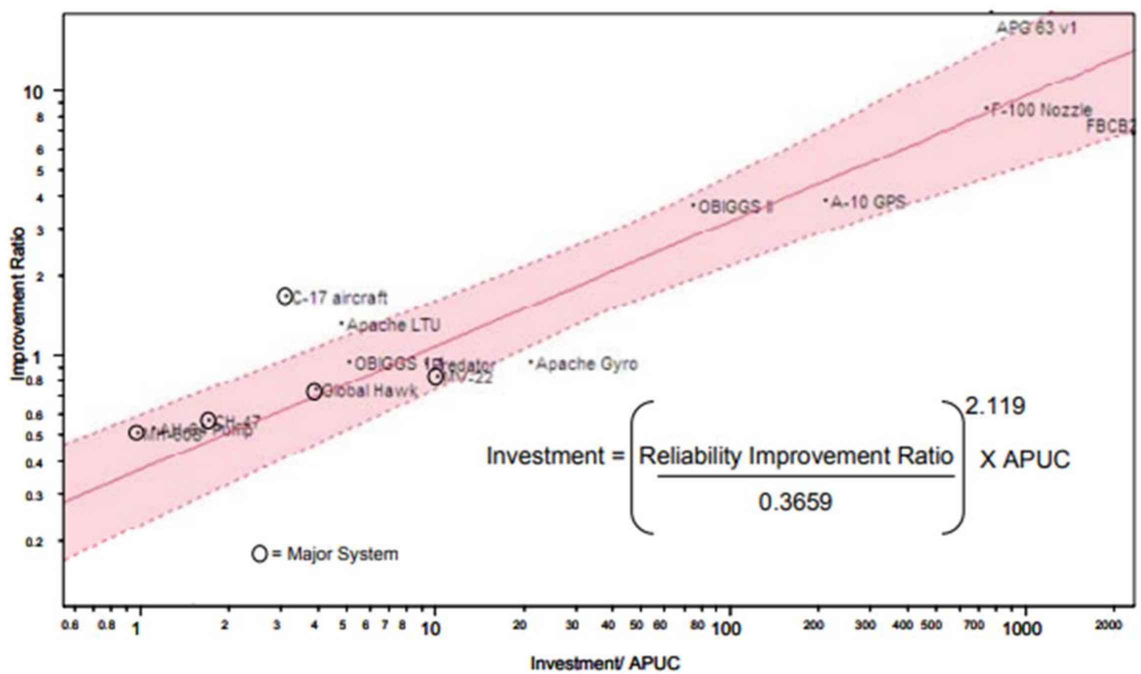
Forbes, J.A., Lee, D.A., and Long, E. A. "Predicting Reliability Investment to Achieve Given Reliability Improvement," 2009 Annual Reliability and Maintainability Symposium, 26-29 June 2009.



Reliability Improvement Ratio = (New MTBx – Old MTBx) / Old MTBx

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Example:
What is the estimated investment to improve reliability from MTBMA of 25 hours to 30 hours for a system with an expected Average Production Unit Cost of $15M?

Reliability Improvement Ratio = (30 – 25) / 25 = 0.2

Investment = (0.2 / 0.3659)^2.119 * $15M = $4.17M

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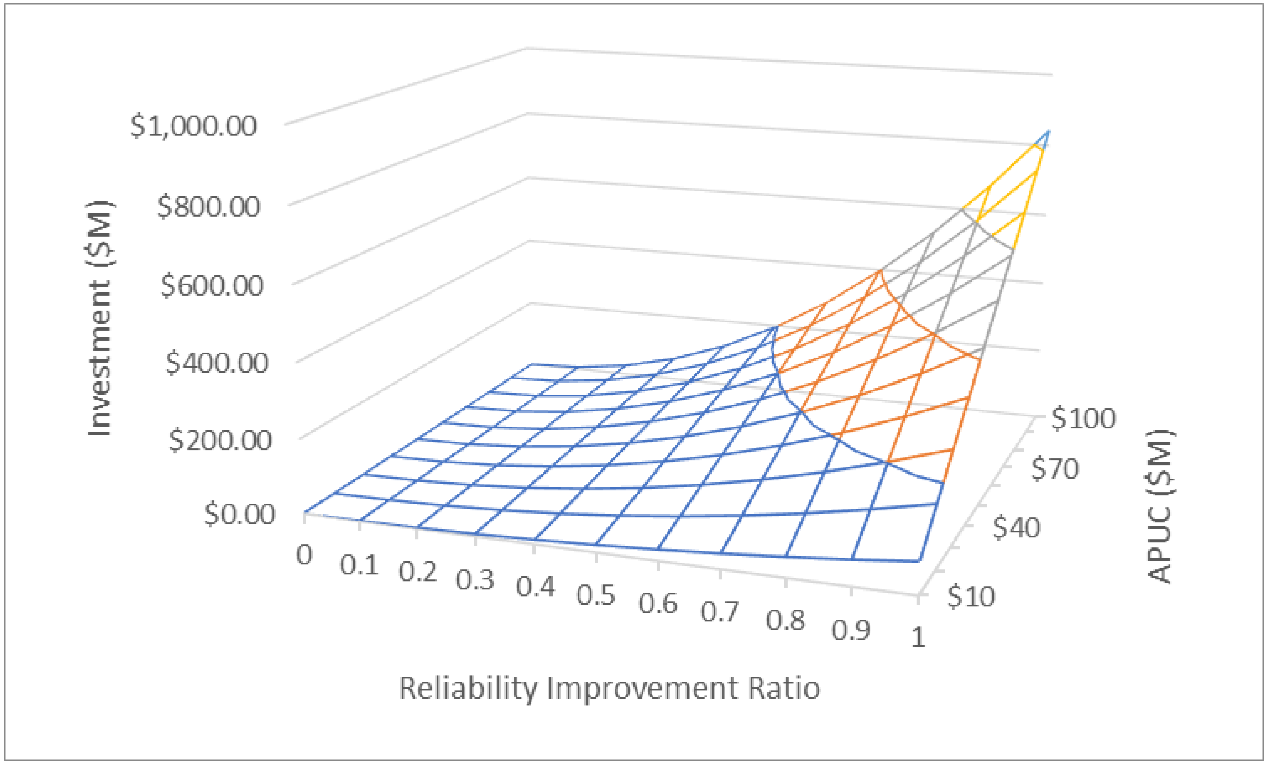

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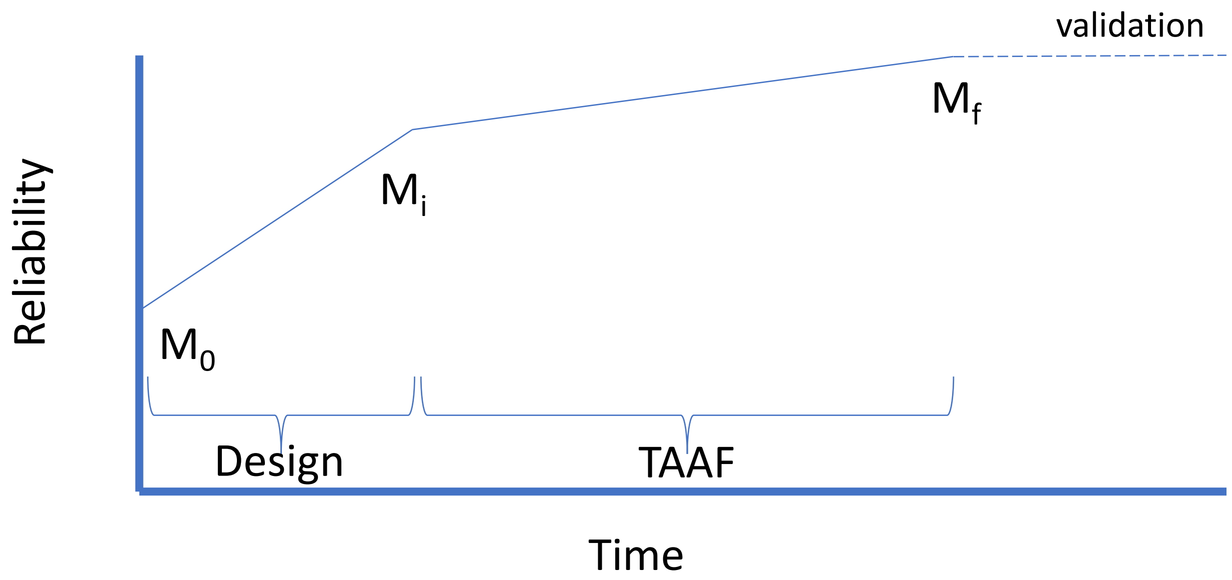

Intermediate Model

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Forbes, J.A., Lee, D.A., and Long, E. A. “Predicting Reliability Investment to Achieve Given Reliability Improvement,” 2009 Annual Reliability and Maintainability Symposium, 26-29 June 2009.

$$\frac{1}{M(\tau)} = \frac{1}{M_A} + \frac{1}{M_i}\left[(1-\mu_d) + \frac{\mu_d}{1+\tau}\right]$$

$$\gamma(\tau) = \frac{1}{cv^2}\left[C_0\tau + \mu_b \ln(1+\tau)\right]$$

$M(\tau)$ → MTBF at non-dimensional time, τ
M_A → MTBF for A modes (failure modes not addressed by corrective action)
M_i → MTBF for B modes at start of TAAF period
μ_d → Fraction reduction in failure rate for B modes addressed by corrective action

$\Upsilon(\tau)$ → Cost at non-dimensional time, τ
cv^2 → Degree to which B-mode failure rates scatter about their mean
C_0 → Initial Cost of operating the TAAF period
μ_b → Average cost incurred by corrective action on B modes

TAAF Model

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$$\frac{1}{M(\tau)} = \frac{1}{M_A^D} + \frac{1}{M_0}\left[(1-\mu_{D)}) + \frac{\mu_D}{1+\tau}\right]$$

$$\gamma(\tau) = \frac{1}{cv_D^2}\left[C_0^D \tau + \mu_B^D \ln(1+\tau)\right]$$

$M(\tau)$ → MTBF at non-dimensional time, τ
M_A^D → MTBF for A modes in design period
M_0 → MTBF for B modes at start of design period
μ_D → Fraction reduction in failure rate for B modes addressed by design (0.7-1.0)

$\Upsilon(\tau)$ → Cost at non-dimensional time, τ
cv^2_D → Degree to which B-mode failure rates scatter about their mean
C_0^D → Burn-in rate of engineering labor in the design period
μ_B^D → Average cost of correcting B modes in the design period

Design Model

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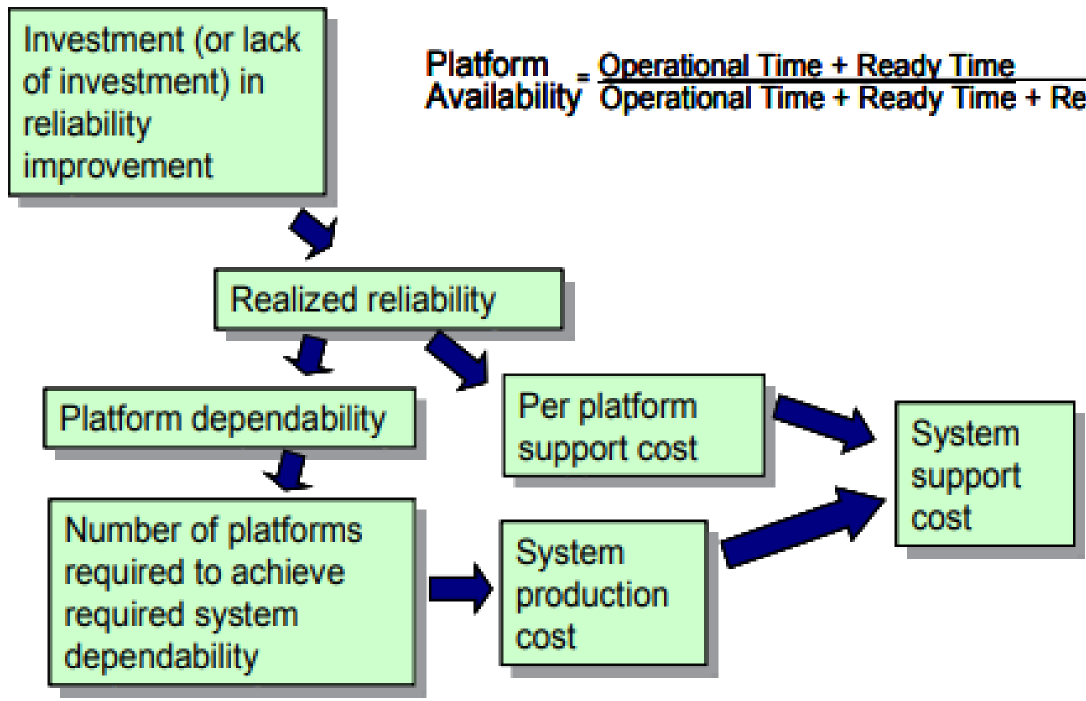
Forbes, J.A., Lee, D.A., and Long, E. A. "Predicting Reliability Investment to Achieve Given Reliability Improvement," 2009 Annual Reliability and Maintainability Symposium, 26-29 June 2009.

$$\text{Platform Availability} = \frac{\text{Operational Time} + \text{Ready Time}}{\text{Operational Time} + \text{Ready Time} + \text{Repair Time}}$$



Production Model Logic

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Mercurio, Salvatore P. and Skaggs, Clyde W., "Reliability Acquisition Cost Study," General Electric Company, November 1973.

$$TC = 1.804(MTBF)^{0.370}(\text{Number of Parts})^{0.684}$$

- Studies the cost of reliability program during development as function of reliability improvement
- Uses 10 avionics equipment systems for air and space applications
- Total Reliability Program Cost (Predictions, FMECAS, etc.) as a function of the resulting MTBF and system complexity (# parts)
- Based on regression analysis

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CONCLUSIONS

- *Most models show a linear relationship (on a log scale) between reliability investment cost and % reliability improvement (power curve or diminishing returns on regular interval scale)*
- *Use %RDTE costs, parts count, or Investment/AUPC to account for variation in system complexity across data*

RECOMMENDATIONS

- *Consider Forbes, et al. basic model in early design phase when there is limited information*
- *During advanced design or TAAF (reliability growth phase), consider Forbes, et al. intermediate models*

Cost modeling can be used with LogSIM to analyze ROI, break-even points and other attributes related to reliability investments

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CONTACT INFO

Dr. Russ Alexander
Email: spectrum.russ@comcast.net
james.r.alexander94.ctr@army.mil
Phone: 256-755-7132
Linkedin: www.linkedin.com/in/russ-alexander-12393913?trk