SE3910 Review Questions (part 1 of 2)

1. What are potential drawbacks of a single expert review?

* A systems engineer cannot be expected to know everything about all disciplines. In this regard it is vital to include experts with a variety of backgrounds to contribute their review of the systems progress.
* Draw backs:
* Interfacing or interoperating sub systems are not reviewed simultaneously
* Strategic imperatives are not identified
* Project priorities are not thoroughly checked
* Project portfolio balance is not thoroughly checked

1. Suppose you’re tasked to run a Delphi Study to forecast the technical needs for Army vehicles. Write a single question for the first round of the Delphi Study. For this question, in the second round, what question would you pose?

* What technical needs do we aim to fulfill with future Army vehicles?
* Who are the technical experts in the field of military vehicles to support this study?
  + The Delphi Study: A forecasting technique that uses a group of experts to iteratively develop a forecast. Developed by RAND corporation for the US DoD in the 1950’s Premise is that group consensus is more valid than individual forecasts

**Delphi Process:**

**Identification of the problem.**

* Prepare problem statement and develop questionnaire

**Selection of experts.**

* Identify and recruit experts

**Administration of questionnaire.**

* Provide experts with background documentation and questionnaire and request responses

**Researcher summarizes responses.**

* Compile responses and determine statistics

**Feedback.**

* The tabulations are returned to the experts, either by mail or in a meeting convened to discuss first round results.
* Additional questions based on first round are developed. Experts are asked to analyze previous questions results and make new predictions.

The process is continued until the level of agreement has reached the pre-determined value.

1. What are some reasons that technology advancement is often exponential?

* Technology improvements leverage improvements in manufacturing, design, and labor reduction through robotic assembly lines. The culmination of several linearly improving technologies lead to exponential improvements in the final end item technology.
* Accelerating Returns Idea:
  + Evolution applies positive feedback – the more capable methods from one generation are used to create the next generation
  + Open system – evolution of a technology can draw upon what happens from outside of that technology stream
  + Success breeds success in that it draws in greater resources (people, money, and other)

1. Why is an ‘S’ curve often a good prediction for how technology will evolve?
   1. Exponential Growth may be limited by physical or economic reasons – leading to an S curve.
      1. Introduction stage – New technology has few researcher working on it, need to overcome bottlenecks before it is practical and meaningful improvements can be made
      2. Growth stage – Greater number of people improving it; standards; positive feedback
      3. Maturity stage – Approaches physical limits, system limits (complexity, size, scale); economic or social limits
2. Which comes first, the technology or the science? Provide examples to help justify your answer.

* Misconception that technology is derived from scientific discovery
* A study of history shows that technology usually comes first
* Theory comes along later to explain the technology
* Example: Thomas Edison Tested Over 3000 Filaments Before He Came Up With His Version of a Practical Light Bulb. Thomas Edison did not have a system of equations to explain electricity.

1. Explain the argument for a combinatorial perspective on technology that says new technologies are composed of previous technologies.
   1. Arthur’s theory of Technology Evolution
      1. A technology is a combination of components
      2. A technology has a central concept or principle
   2. Innovation by context – an example

In 1991, inventor Trevor Baylis saw a television programme about AIDS workers in Africa. In poor countries radio broadcasting had always played a part in health education, but in this programme the workers were explaining how batteries were expensive or unavailable and electricity supplies unreliable or simply non-existent. The programme provided Baylis with a problem, and inspired him to find an innovative solution.  
  
Baylis's invention, as you have probably guessed, was the clockwork radio, see Figure 2 below. He wasn't the first person to use springs to generate electricity, but prior to his design the energy had only ever been produced this way for short bursts at a time – here is the context. The innovation is in applying springs to the provision of low-power electricity for consumer electronics. Baylis invented a mechanism that gave forty minutes of play from just twenty seconds of winding. The winding action coils a spring, attached to a gearbox, which is connected to a dynamo. When the spring is released the gearbox controls the steady discharge of energy to produce electricity, and the radio works. The dynamo provides three volts at between 55 and 60 milliwatts, but the design also incorporates a solar-powered source to extend its performance.

1. **In military acquisition, which comes first the capability need or the technology looking for an application? Provides examples to help justify your answer.**<https://cle.nps.edu/access/content/group/0230bdf9-b948-407a-a35d-99ce7f579739/Military%20Affairs/hughes-ChapterTrendsConstantsofTechnology.pdf>  
   This is a tough one because there are examples each way. But generally, the military need has come first with the technology developed afterwards. I attribute this to the fact that many technologies only have a military application. Notable examples:  
     
   Cryptographic systems (World War II Enigma box, and the counter system developed by the allies)  
   Jet aircraft  
   Submarines  
   Radar  
   Sonar  
   Nuclear weapons  
   Solid State Rockets
2. **Do you agree with Plato’s widely quoted statement that necessity is the mother of invention? Explain why or why not.**

<https://cle.nps.edu/access/content/group/0230bdf9-b948-407a-a35d-99ce7f579739/TechnologyDefined/SE3910-IntroductionTechnology.pdf>  
First Lecture, Slide 14-16. Professor states that technology does not always come after science. Also, it is false to say that there is always a need before a technology is developed. Most technologies don’t fit within Maslow’s Hierarchy of Needs. Also, people continually change their needs to include more things. “Technology fulfills superfluities.” Development of the fork as an example.

1. **Write a definition of technology.**<https://cle.nps.edu/access/content/group/0230bdf9-b948-407a-a35d-99ce7f579739/TechnologyDefined/Technology_Matters_Questions_to_Live_With_1_Can_We_Define_Technology__1_.pdf>

Nye’s book has several pages on the history of the term, starting at page 12. The notes from the first lecture summarizes it as  
“Technology is a means to fulfill a human purpose: the knowledge, the object, and the method.”

1. **Making an internal combustion engine that obtains better fuel mileage is an example of: (i) innovation by context, (ii) innovation by development, or (iii) invention? Explain your answer.**

Reference: Section 1.3-1.4  
  
(i) No, this is not a new application

(ii) “Innovation by development is about changing the bit that doesn't work, or that could work better, to improve the function of the whole for reasons of cost, performance, ease of manufacture or competitive edge.” Yes, correct answer because improving gas mileage is a good example of using small innovations to make something work a little bit better. Low risk.

(iii) This is clearly not a new technology

1. **Does Arthur’s theory of technology evolution utilize the same mechanisms of natural selection and survival of the fittest as the Darwinian theory of evolution for species?**https://cle.nps.edu/access/content/group/0230bdf9-b948-407a-a35d-99ce7f579739/TechnologyDefined/Arthur-NatureTechnologyChapter1.pdf  
   Chapter 1  
     
   Partially, technology that previously exists tends to develop to suite a local environment. For example, small cars in urban environments vs large trucks in rural environments. But some technologies just appear, and cannot be traced back easily to earlier versions. Examples cited are jet engines, radar, railroad locomotion, etc.
2. **Explain the tenets that build Arthur’s theory of technology evolution?**Chapter 1 and 2  
   - Combinatorial evolution. Technology is created from previous technologies. “Novel technologies must somehow arise by combination of existing technology.”  
   - Novel also comes technology comes from the “constant capture of new natural phenomena and the harnessing of these for particular purposes.”  
   - Technology consists of parts, systems and subsystems. This is the structure of technology.

* Technology is also modular, with subassemblies forming larger components

1. How can we test whether Arthur’s theory of technology evolution is valid?  
   Arthur addresses this in Chapter 2 of “The Nature of Technology” (Combination and Structure). In this chapter he stresses the piecewise composition, or modularity, by which technology is developed (evolves). The most straight-forward way to test Arthur’s theory, therefore, is through decomposition. If we can sufficiently decompose technology into a taxonomy of underlying pieces then we increase our confidence in his theory. He gives the example of a hydroelectric power generator which, “combines several main components: a reservoir to store water, an intake system with control gates and intake pipes called penstocks, turbines driven by the high-energy water flow, electricity generators driven by the turbines, transformers to convert the power output to higher voltage, and an outflow system, or tailrace, to discharge the water.”
2. Use the principles from systems architecting to explain the mechanisms defined in Arthur’s theory of technology evolution.  
   Arthur addresses this in Chapter 2 of “The Nature of Technology” (Combination and Structure). The answer lies in Arthur’s view of the modularity of technology and is analogous to how system architecting relies on building up complexity through modular design. In systems architecting we take requirements and map them to solutions which may, themselves, be composed depending on the level of abstraction in the system. The components satisfy requirements and define (expose) interfaces with which they can be connected and interact with other components. By this mechanism, we create abstraction through encapsulation of technology and build complexity by focusing on the interfaces. In this way, systems architecting parallels the mechanisms defined in Arthur’s theory of technology evolution.
3. Explain why there is variety in technologies? Why not just have a single car design? A single vacuum cleaner design? Or a single design for any technology.  
   In “The Evolution of Technology” from lesson 2, George Basalla in Chapter 1 (Diversity, Necessity, and Evolution) discusses this under the heading, “Diversity.” He draws a comparison between the evolution of technology and the evolution of living things, “The variety of made things is every bit as astonishing as that of living things.” He says that necessity and utility alone are insufficient to account for the technological diversity and suggests the “applying the theory of organic evolution to the technical world,” citing deeper assumptions about the meaning and goals of life.
4. Why is it argued that technology is culture-bound? Provide some examples.  
   In “The Evolution of Technology” from lesson 2, George Basalla in Chapter 1 (Diversity, Necessity, and Evolution) discusses this later in the chapter. He says, “We cultivate technology to meet our perceived needs, not a set of universal ones legislated by nature.” He then goes on to describe the cultural drivers to our perception of needs. He draws on the invention of the wheel as an example of cultural influence in the evolution of technology. He says, “A bias for the wheel led Western scholars to underrate the utility of pack animals and overemphasize the contribution made by wheeled vehicles…” He summarizes, “This history of the wheel begain as a search for a significant technological advancement that was produced in response to a universal human need. It has ended with the wheel seen as a culture-bound invention whose meaning and impact have been exaggerated in the West.
5. Suppose the tensile strength of carbon nano-tubes is observed to follow exponential growth that results in doubling every 3 years. If the current tensile strength is x MPA (mega Pascals), then what will the tensile strength be in 3 years? In 6 years? In 12 years?  
   3 years: 2x = 2^(1)x = 2x  
   6 years: 2(2x) = 2^(2)x = 4x  
   9 years: 2(2(2x)) = 2^(3)x = 8x  
   12 years: 2(2(2(2x))) = 2^(4)x = 16x
6. What makes a good forecast?  
   From the lecture notes for lesson 3 (Technology Forecasting) reference slides 5, 6, & 7. The following is taken verbatim.  
   **Slide 5:** A good forecast?  
   Accuracy is of course desired – but you won’t know until it happens -> actionability of conclusions makes a forecast successful  
   Quality of underlying data (Currency, Completeness, Potential bias)  
   Quality of analysis that lead to forecast (Qualification of experts, Bias, Balance)  
   **Slide 6:** How Can You Judge a Forecast Before the Fact?  
   Are assumptions specified?  
   Is quantitative evidence included?  
   Does it follow a path of logic?  
   Is the projected rate of improvement comparable to prior rates?  
   If the forecast breaks from the past are substantial reasons offered?  
   Does it provide a basis for rational discussion?  
   **Slide 7:** NSA Advice for better forecasts  
   Evaluate technology in terms of market megatrends (Ever increasing bandwidth, Greater user mobility, Inventions against these trends are less likely to succeed, whereas those that advance it are more likely)  
   Anticipate the interplay of new technologies
7. Name some reasons that most technologies cannot continue to evolve exponentially forever.
8. What is a technology roadmap?
9. What is backcasting?
10. What is a revolution in military affairs? What makes it revolutionary?
11. Does technology provide a decision advantage that has affected the outcome of a war?
12. What are the elements required for a revolution in military affairs according to Krepenivich?
13. What is military doctrine?

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**slide 7 lecture notes**

“Doctrine is what is officially approved to be taught—whether in a service school or an operational unit engaged in training about what methods to use to carry out a military objective.” I.B. Holly, Technology and Military Doctrine, Air University, Maxwell Air Force Base, AL, 2004, page 1.

The Dictionary of US Military Terms for Joint Usage, doctrine is “authoritative but requires judgment in application.”

**From an internet search, the *DOD Dictionary of Military and Associated Terms:***

“Fundamental principles by which the military forces or elements thereof guide their actions in support of national objectives. It is authoritative but requires judgment in application.”

1. Why does Hughes argue that technology usually does not affect the outcome of a war?



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1. Describe the current revolution in military affairs and how it affects defense acquisition, strategy, and other aspects of the military.

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**Page 1**

“Revolutions in Military Affairs (RMA) and transformations are uncommon phenomena. They entail fundamental and disruptive discontinuities. To date, the US transformation enterprise has fallen short of the RMA hype. It entails incremental advances with little evidence of generation-skipping technologies and has so far had only modest impact on US procurement programs. Hence US military transformation is unlikely to pose insurmountable challenges for the US defense industrial sector. In particular, the systems integration innovation required to realize network centric warfare is primarily sustaining rather than disruptive, requiring suppliers to build on existing, not develop new, capabilities. Close supplier-customer relationships in this sector, the emphasis on sustaining innovation, and the scale of the systems integration work required constitute formidable barriers to entry for new systems integrators, including commercial information technology (IT) firms. These barriers are being reinforced as Boeing, General Dynamics, Lockheed Martin, Northrop Grumman, and Raytheon invest heavily in organic IT capabilities.

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Where are we on the continuum stretching from one military-technical regime to another (i.e., from the "old" regime to the "new" one)? Our initial work indicates that we are probably in the early stages of a change that could run another one or two decades. We have yet to witness the kind of military event like France in 1940, the Battle of Britain, or the Battle of the Coral Sea that clearly demonstrates a revolution in warfare has taken place.

1. What does a lead systems integrator do?

I couldn’t find anything in our reading or lectures, but here’s a definition

A lead systems integrator is a contractor, or team of contractors, hired by the federal government to execute a large, complex, defense-related acquisition program, particularly a system-of-systems (SOS) acquisition program. A lead systems integrator can have broad responsibility for executing their programs, and may perform some or all of the following functions: requirements generation; technology development; source selection; construction or modification work; procurement of systems or components from, and management of, supplier firms; testing; validation; and administration.

1. How does adoption of a technology affect our environment? Consider a major technology, and explain how it has affected our environment.
2. Obviously, this answer will vary…think internet, automobile, telephone, etc.
3. How does the theory of technology evolution support the outcome of exponential growth in technology?
4. What is Augustine’s Law?
5. What is the difference between forecasting evolutionary technologies and disruptive technologies? What is a disruptive technology?
6. What is the technology readiness level? What does a value of 1 imply compared to a value of 9?
7. How is the technology readiness level used by the DoD?