Choosing a Research Topic

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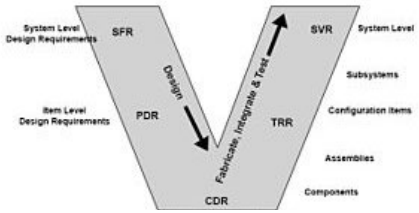
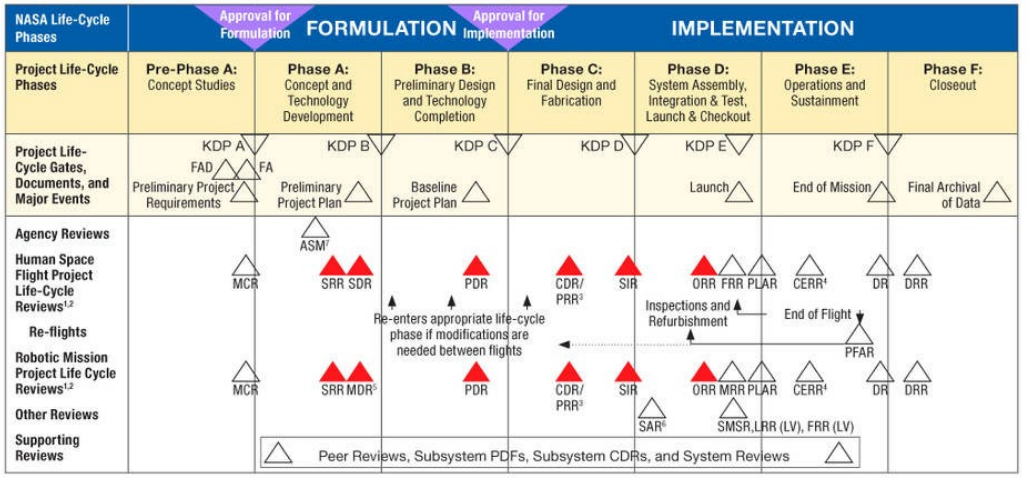
Agenda

- Systems Engineering Research
- Research Topics
- Research Problems
- Research Tasks
- Communicating Research Topics
- Conclusions

Research in Systems Engineering

- When we talk about research in systems engineering, we are going to give ourselves a broad license to innovate
  - Engineering is the practice of organizing the design, construction, operation of any artifact that transforms the physical to meet some recognized need (Rogers, G., The Nature of Engineering, 1983)
  - "Research is the careful, well-defined, objective, and systematic method of search for new knowledge" (Deb, E., et al., Engineering Research Methodology, Springer 2019)

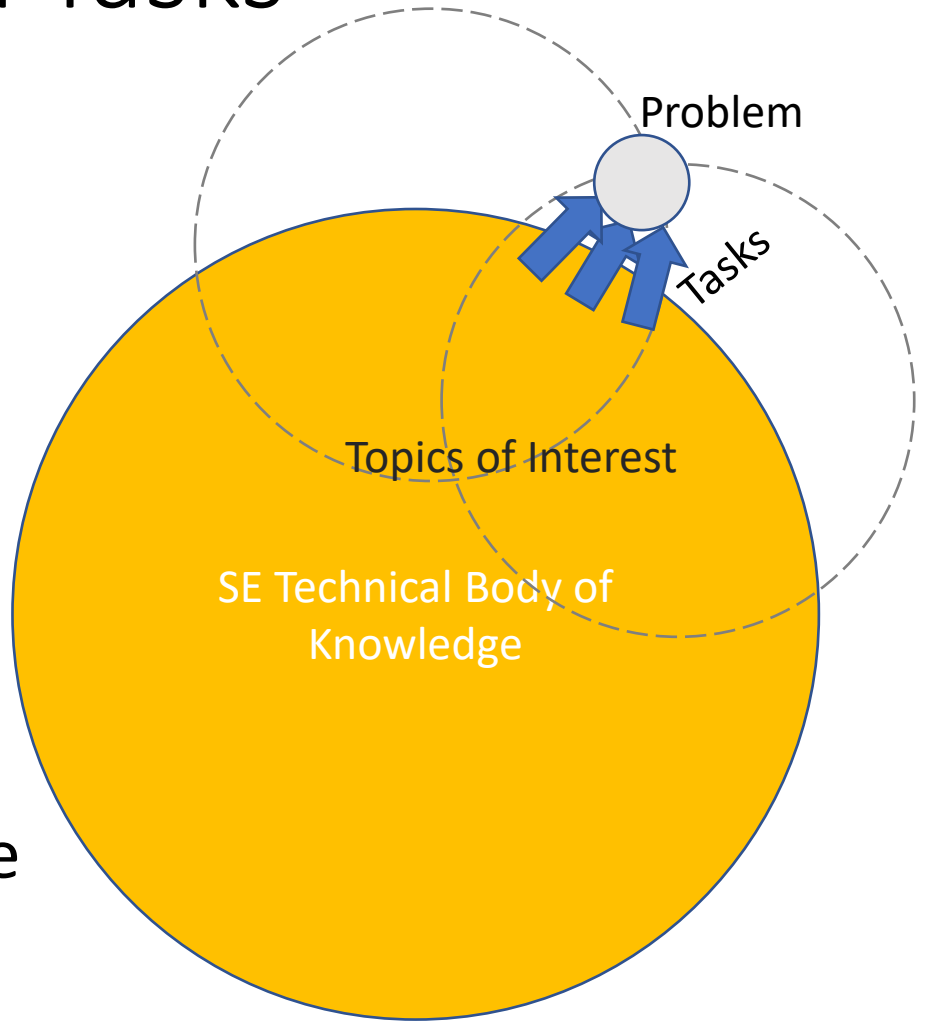




new knowledge can be researched for ANY stage of the system lifecycle

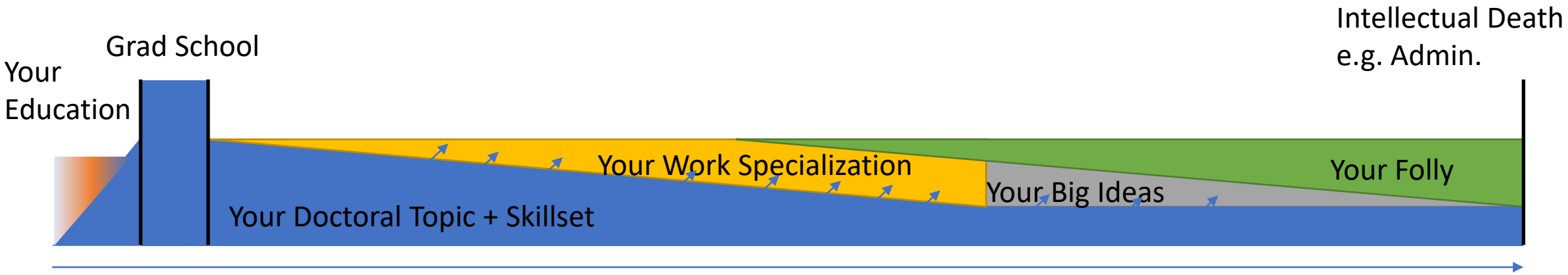
Research Topics, Problems, and Tasks

- Research seeks to add new knowledge to the SE body of knowledge
- **Research Topics** define the application domains, theories, frameworks, in which we will perform research
- **Research Problems** define problems that we don't have the answers to
- **Research Tasks** define the process by which we will find solutions to the research problems



What makes for a good research topic?

- Philosophically, a SE research topic should be:
- ***Aligned with your long-term interests and understandings***
  - At the end of your research process, you will be the world expert in _____.
  - You will be building on your Doctoral topic and skillsets for much of your intellectual life

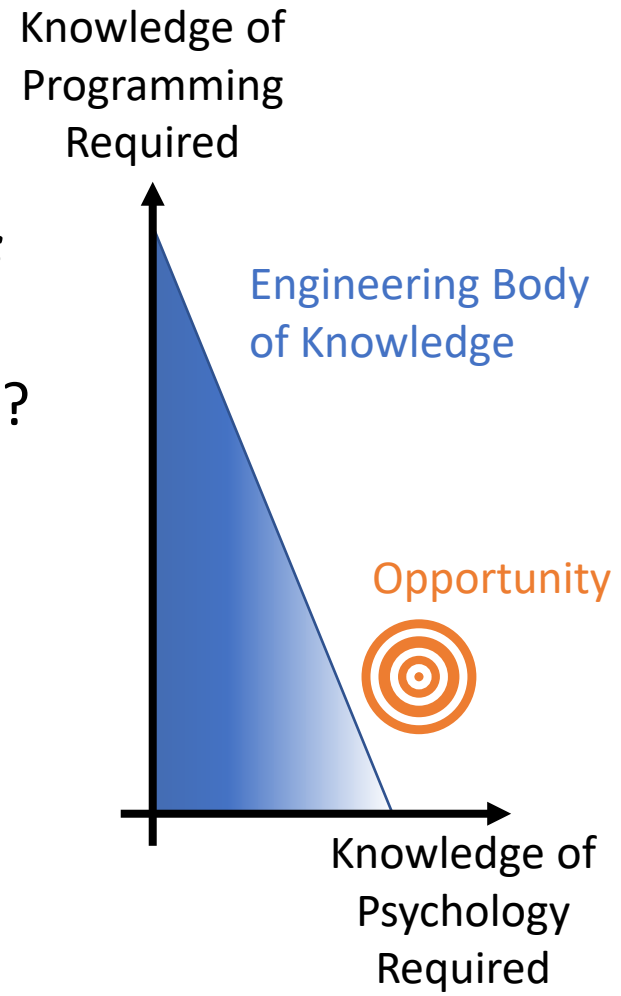


What makes for a good research topic?

- Philosophically, a SE research topic should be:
- ***Aligned with your advisor's or collaborator's interests***
  - Many SE advisors have broad and multitudinous interests in SE, but we must have some shared ground to build on
  - Your advisor's skillsets will feed your shared big ideas

What makes for a good research topic?

- Philosophically, a SE research topic should be:
- ***Built on the foundation of your skillsets and capabilities***
  - Know yourself and you capabilities. What do your friends and family recognize you for? What do you do, that is not ordinary?
  - Some students are good at building things.
  - Some students are good at programming.
  - Some students are good at talking to people.
  - Some students are resourceful.
  - Some students have great insight from their history.
  - Some students are good at lab work.
  - Some students are good at writing.



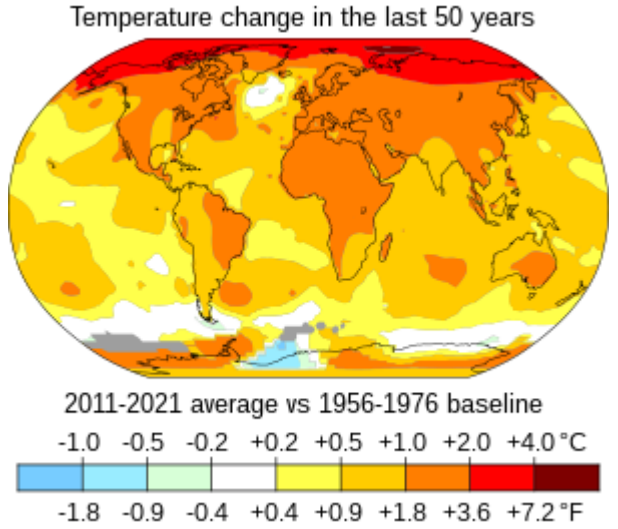
What makes for a good research topic?

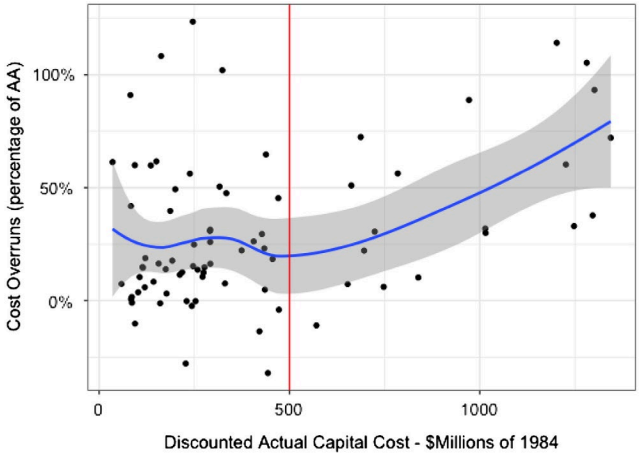
- Philosophically, a SE research topic should be:
- ***Enabling you to learn something big.***
  - When you imagine yourself 10 years in the future, what are you doing? What are the skills that you want to have.
  - Being at the University is about having time/space/support to make investments in yourself
  - There are only a couple of times in life when you are pushed/enabled to stretch yourself

https://aerospace.honeywell.com/us/en/learn/supported-platforms/space/human-space

What makes for a good research topic?

- Philosophically, a SE research topic should be:
- ***Responsive to an authentic need or problem.***
  - Look critically at the engineered world around us
    - Question assumptions
    - Diversify your perspectives
    - What is working, and what is not working?
  - Critique the guidance from authority sources
    - https://www.nae.edu/19649/Reports
    - https://www.osti.gov/biblio/1561164
  - At this point, your topic can include a big, hairy problem



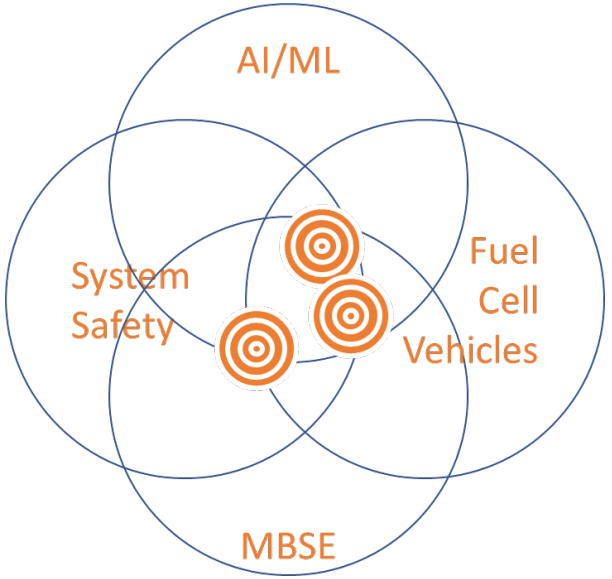


https://ascelibrary.org/doi/abs/10.1061/(ASCE)CO.1943-7862.0001827

What makes for a good research topic?

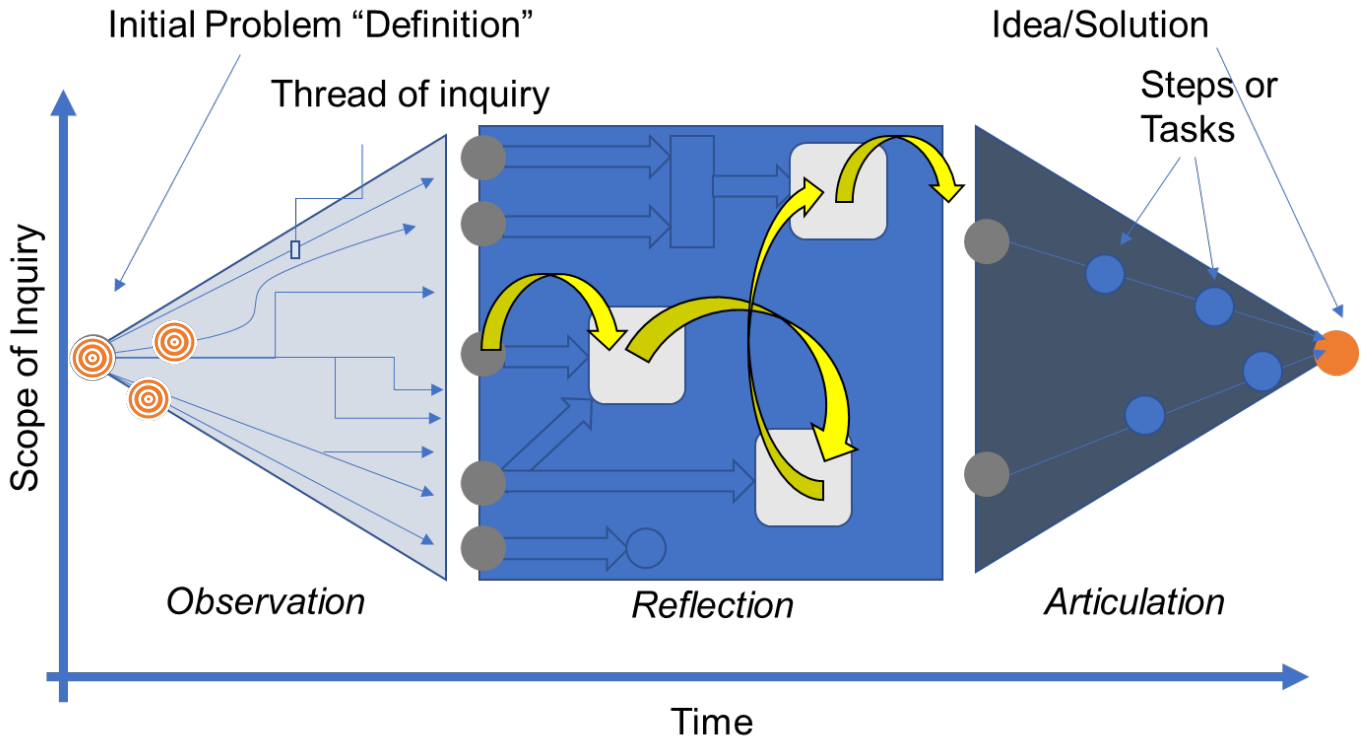
At the overlap of all of those considerations is a broad topic in which you will be studying

- “My research topic is in the field of Model-based Systems Engineering applied to responsive and transient space-based communication and networking.”
- “My research studies System Safety frameworks for AI-enabled powerplant control in vehicles.”



What makes for a good research topic?

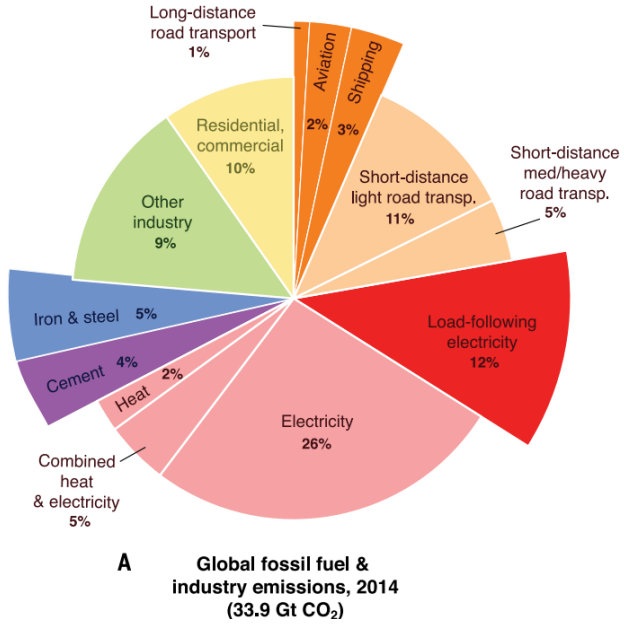
- Let's assume that there is >0 space at the intersection of those criteria
- Your goal is to now ideate some practical research problems in and around the feasible space.
- Recognize that uncertainty is still high – much could go wrong



- **Observe** - **Reflect** - Articulate

What makes for a good research problem?

- Practically, a SE research problem should be:
- ***Reactive/constructive to others' work in the research topic***
  - Accept that there is already work going on in your preferred research topic
  - There are many options for posing a research problem responsive to the field
    - Are others solving the right problem?
    - Are others solving the problem sub-optimally?
    - Are others not seeing the big picture?
    - Are others not appreciating the detail of how this problem manifests in reality/industry/government?

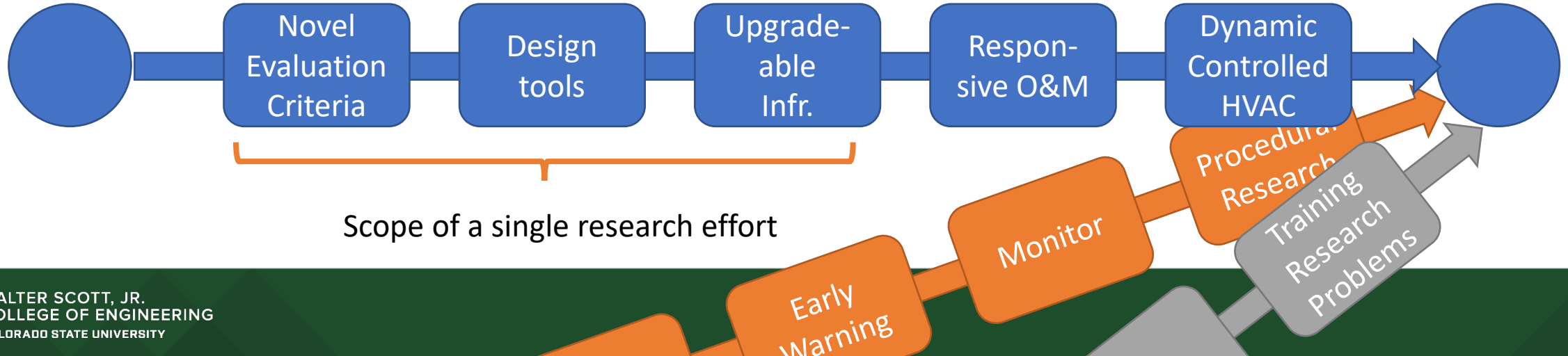


A Global fossil fuel & industry emissions, 2014 (33.9 Gt CO_2)

What makes for a good research problem?

- Practically, a SE research problem should be:
- ***One part of a series or composite of research problems***
  - Many research topics will take a lifetime to investigate and solve
  - Understand your research problem in terms of its contribution to the field, not in terms of its "solution" to the problem

A pandemic-ready VHA



What makes for a good research problem?

- Practically, a SE research problem should be:
- ***Asking questions that expand what we know, and problems that define what we do not know***
  - How do you prove the negative, how do you show what the field does not know?
    - Compare, contrast, evaluate others' recent work
    - Refer to review articles, books, or others' future work section
    - Refer to recent failures
    - Criticize commonsense
    - Measure the unmeasured

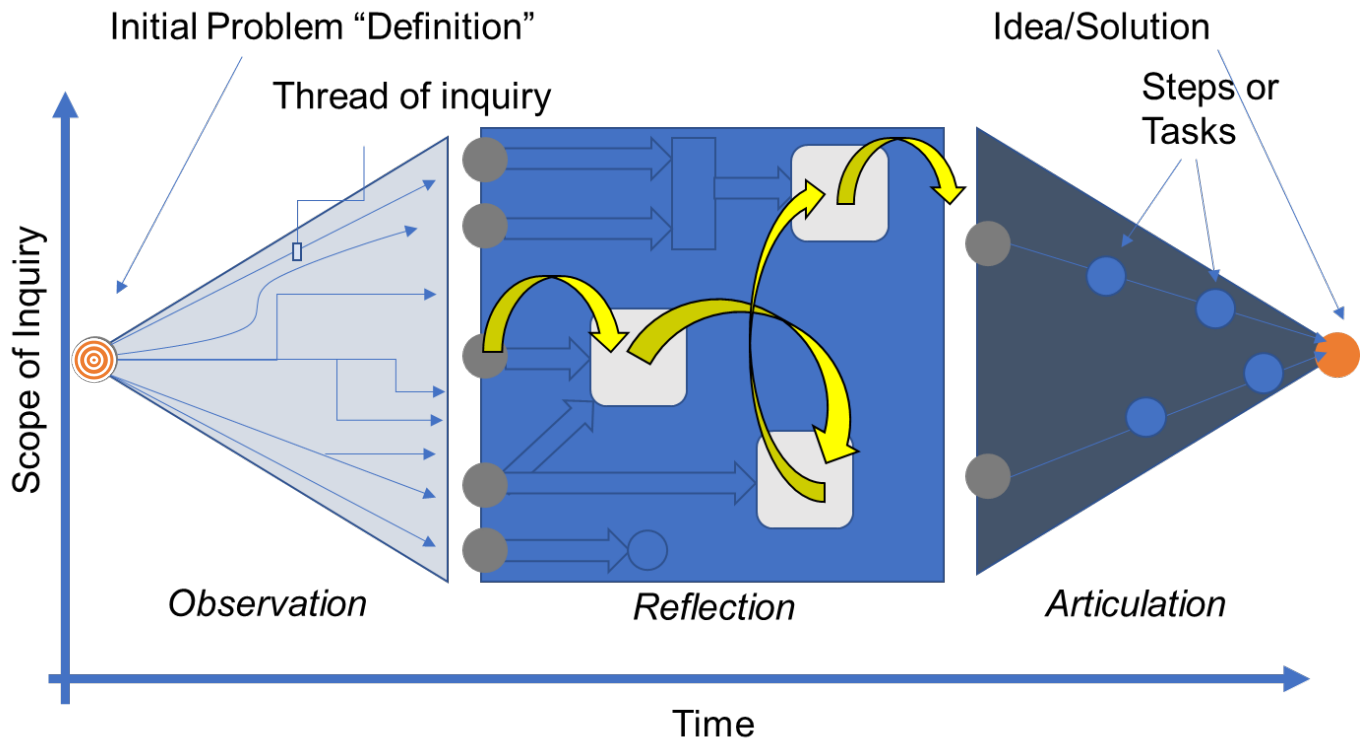
https://www.floridatoday.com/story/news/local/2020/08/12/burning-truck-shuts-down-95-southbound-near-port-st-john/3361003001/

What makes for a good research problem?

- Practically, a SE research problem should be:
- ***Defineable as a Systems Engineering problem***
  - Is it a systems problem or a disciplinary problem?
  - Is it an engineering problem or … a science problem, a philosophy problem, a management problem?
  - The student must define for the audience that this is a problem appropriate to a Systems Engineering treatment.
    - Define your problem/application in terms of its components, interfaces, dynamics, perspectives, environment, trans-disciplinarity, lifecycle thinking

What makes for a good research task?

- Let's assume that there is >0 research problems that you can identify
- Research demands a "defined and systematic method"
- Your goal is now to articulate some stepwise tasks that will lead us closer to solving the problem
- **Observe - Reflect - Articulate**



What makes for a good research task?

- Practically, a SE research task should be:
- ***Built on research/discovery/synthesis verbs***
  - Each research task should be a unit of research activity and should have concrete outcomes
  - Research activities can include:
    - Measurement, literature review, quantification, survey, synthesis, design, architecting, comparison, development, etc.
  - Research activities should not include: ~~Demonstration, implementation of best practices~~

"Compare and report the characteristics of the set of explainable AI technologies to the needs of the ISO system safety process."

~~"Find ISO system safety process."~~ ~~"Research explainable AI in System Safety"~~

What makes for a good research task?

- Practically, a SE research task should be:
- ***Supportable by available time, tools, data, experts, and experiments***
  - There is not much value in proposing research tasks that you don't have the resources to accomplish.
  - The University has access to extraordinary resources in measurement, computing, libraries, etc., but not infinite.
- In my experience, most research fails because of lack of resources (we ran out of time, not enough data)
- There is always an irreducible risk of failure

What makes for a good research task?

- Practically, a SE research task should be:
- ***Step-wise contribute to new knowledge and solving the research problem***
  - It does not have to solve the problem in one swoop, but each task must build on others to generate new knowledge
  - Short-hand example:
    - Task 1 – Develop and Validate sub-system models from experimental and theoretical relations
    - Task 2 – Compare computer-based, parametric, and optimizable system design to the state of the art
    - Task 3 - Induce optimal subsystem relations from the set of optimized designs
  - You should expect to learn as you go

Communicating Your Research

- By thinking about research topics in this way, it can help when you communicate your research to others
- Proposal/Dissertation/Defense
  - These workproducts of the research process can be presented explicitly in your document
    - The **Introduction** to your dissertation defines the research topic
    - **Background** and **Research Questions** define the research problems that you are solving
    - **Research Tasks** can be associated with each Research Question

Communicating Your Research

- The Research Elevator Pitch (1 min)
  - What is your **topic** ?
  - What is the **problem, or question** that you are asking and addressing in your research?
  - **How** are you uniquely addressing this problem, issue or question?
  - Why is that problem interesting and important?

https://www.intheblack.com/articles/2018/10/02/how-to-network-at-conferences

Conclusions

- The objective of graduate school is to build the capabilities for a life and career of scholarship, curiosity and innovation
- Defining and revising research topics, problems, and tasks is one that you will exercise continuously as you build your R&D career
- This is a difficult, uncertain, risky process… make a team with your advisor and collaborators.