Does Systems Engineering Drive Innovation? A Case Study

Vehicle Flood Warning System with Sensor Optimization and Predictive Algorithm

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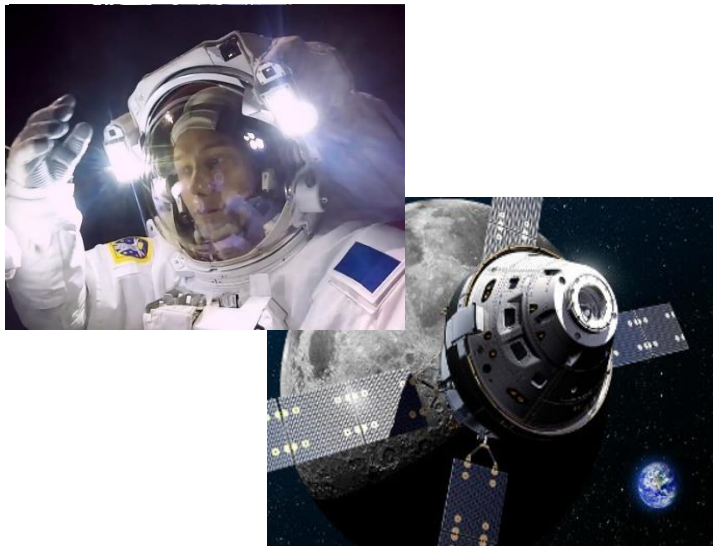
Scope of Discussion

- This presentation is not about ….



… But an analogy that allows us to more freely discuss the application of SE at the nascent stage

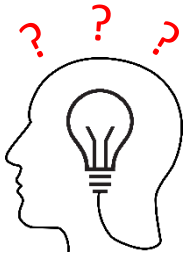
FWS

Scope of Discussion – Flood Warning System

- Flooding in urban areas, driven by precipitation and high tide events, can have a dramatic impact on a region's transportation system and economic viability.
  - In August 2017, Hurricane Harvey flooding destroyed 500,000+ vehicles along the Gulf Coast, resulting in nearly $10B in losses
- For this presentation, we will focus on the inventive conception stage, right at the beginning and spark of imagination
  - We will explore the SE tools and steps to take in this embryonic development process using an invention example called Flood Watcher, an early warning flood detection system
  - The process uses a multi-disciplinary SE approach to predict roadway flooding and to mitigate driving danger from flooded roads, by establishing a smart vehicle flood warning system which knows when and where vehicle flooding could happen with a high degree of certainty
  - Adoption of the formation process is applicable to any field, from Aerospace to Oil and Gas

Innovation Process – SE Phase Definition

- Does Systems Engineering drive and influence the invention process?
- Innovation can occur during all life-cycle phases, but is predominant in research and conception

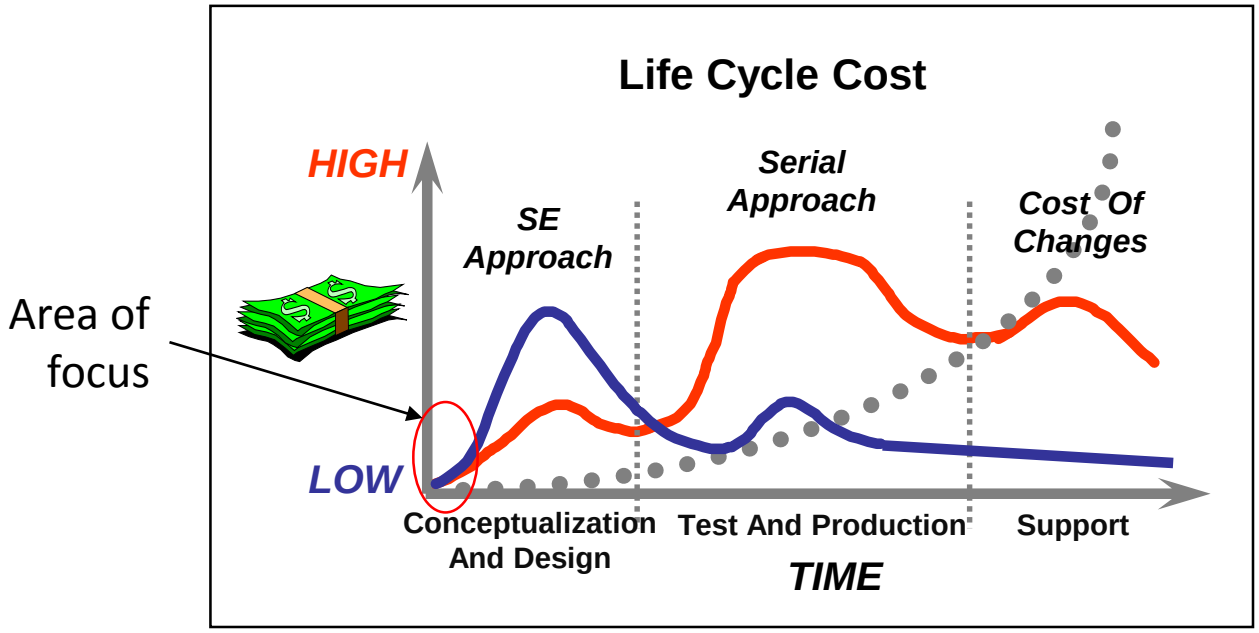


LIFE-CYCLE STAGES	PURPOSE
EXPLORATORY RESEARCH	*Identify stakeholders' needs* *Explore ideas and technologies*
CONCEPT	*Refine stakeholders' needs* *Explore feasible concepts* *Propose viable solutions*
DEVELOPMENT	*Refine system requirements* *Create solution description* *Build system* *Verify and validate system*
PRODUCTION	*Produce systems* *Inspect and verify*
UTILIZATION	*Operate system to satisfy users' needs*
SUPPORT	*Provide sustained system capability*
RETIREMENT	*Store, archive, or dispose of the system*

Source: INCOSE's Systems Engineering Handbook

Systems Engineering Support Phases

- Application of systems engineering to the design, development, and support of complex systems has been shown to reduce cost and schedule overruns
- We will look more intently at SE processes at the beginning, not just for cost/schedule, but opportunity for innovation

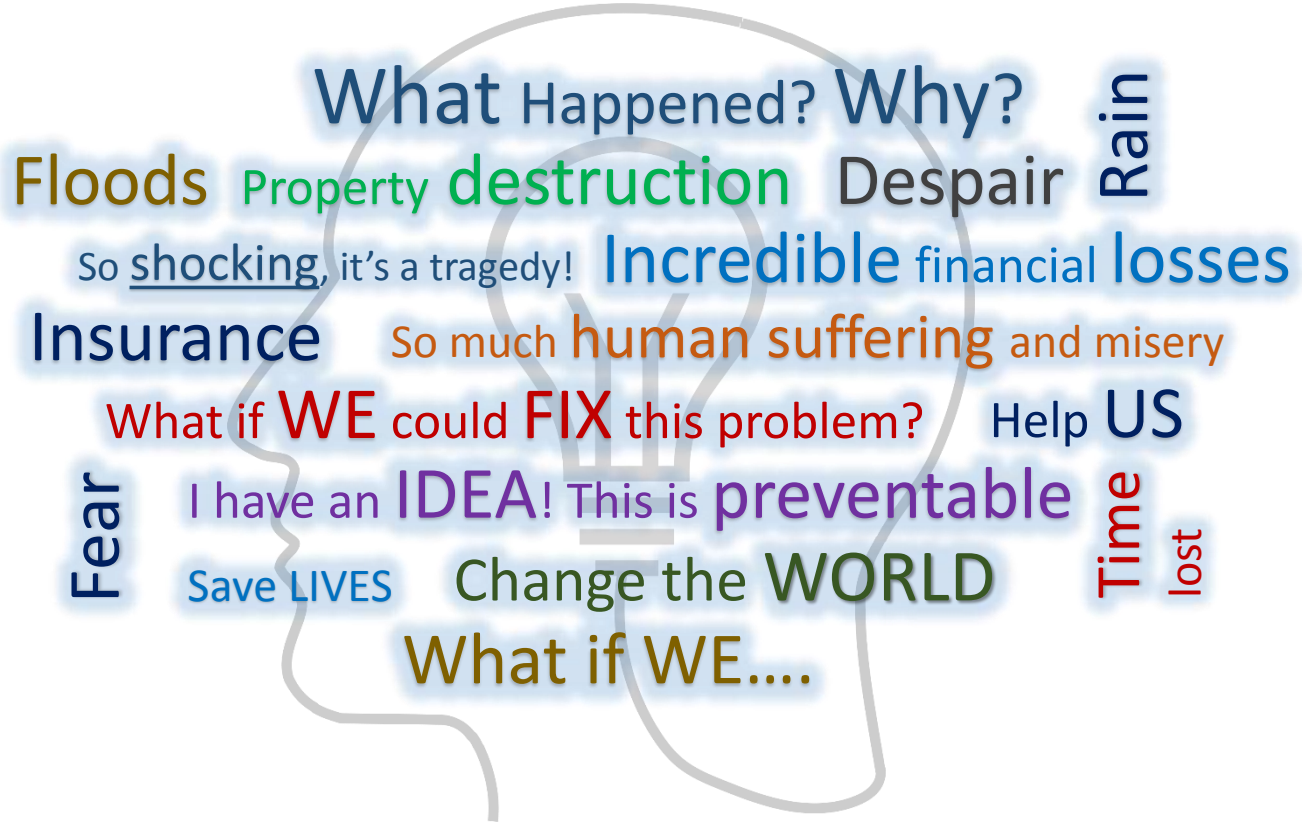


Innovation Process – Define the Problem

- In the last 2 years, there have been at least three major floods in the Gulf Coast area affecting vehicles on the road – this alarming trend is only increasing, with the last being Hurricane Harvey
- Will this '*Unprecedented*' disaster be the last one?
- Can we count on our road systems being flood-free in the future?

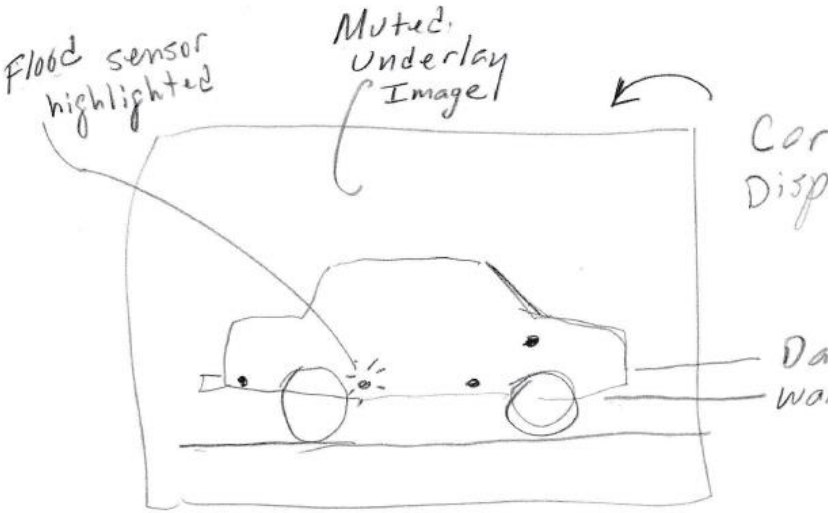
Innovation Process – Word Cloud

- What are the voices? How are people affected?
- How is the problem-solution defined?
- Create a Word Cloud to distill information



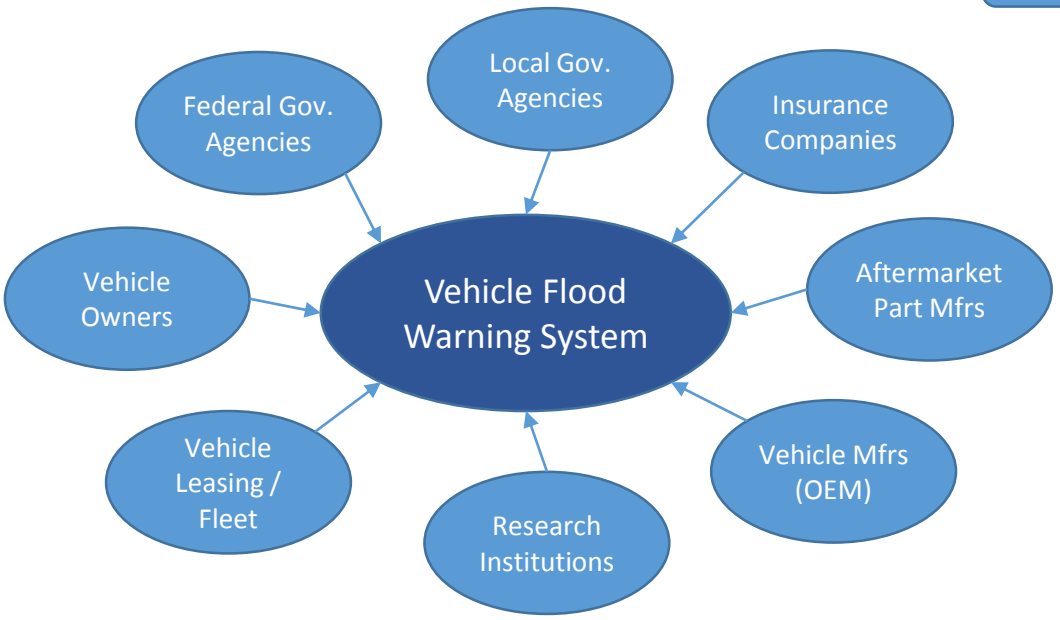
Innovation Process – Baseline Concept

- Instead of driving blind into a flood….
- Sketch out an idea for a possible solution (displays shown)

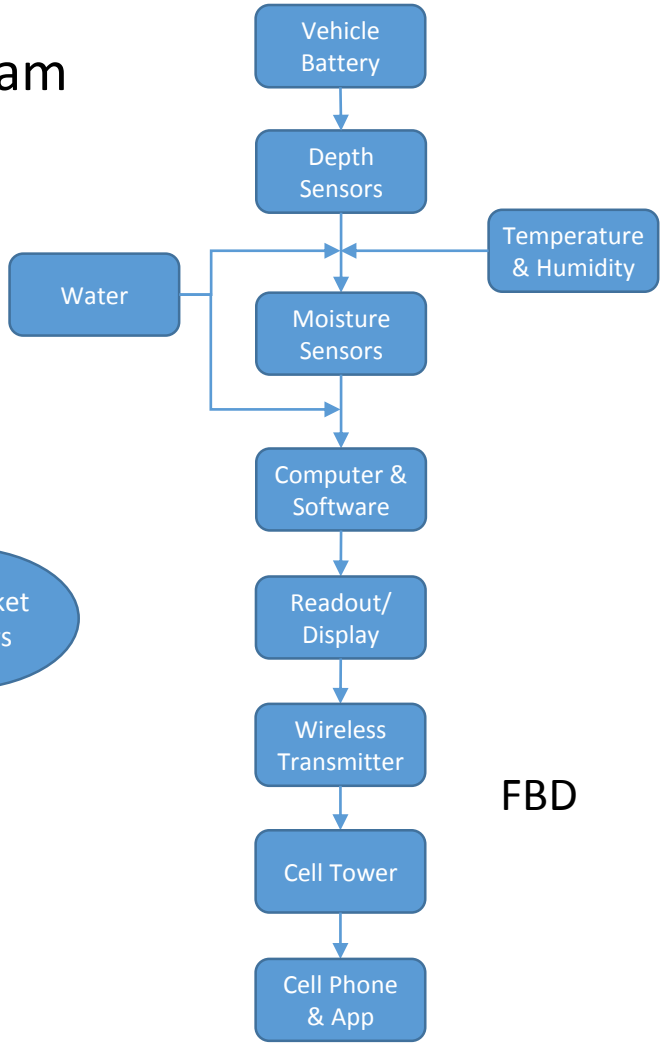


Innovation Process – Baseline Concept

- Draw a Context Diagram
- Sketch out a Functional Block Diagram



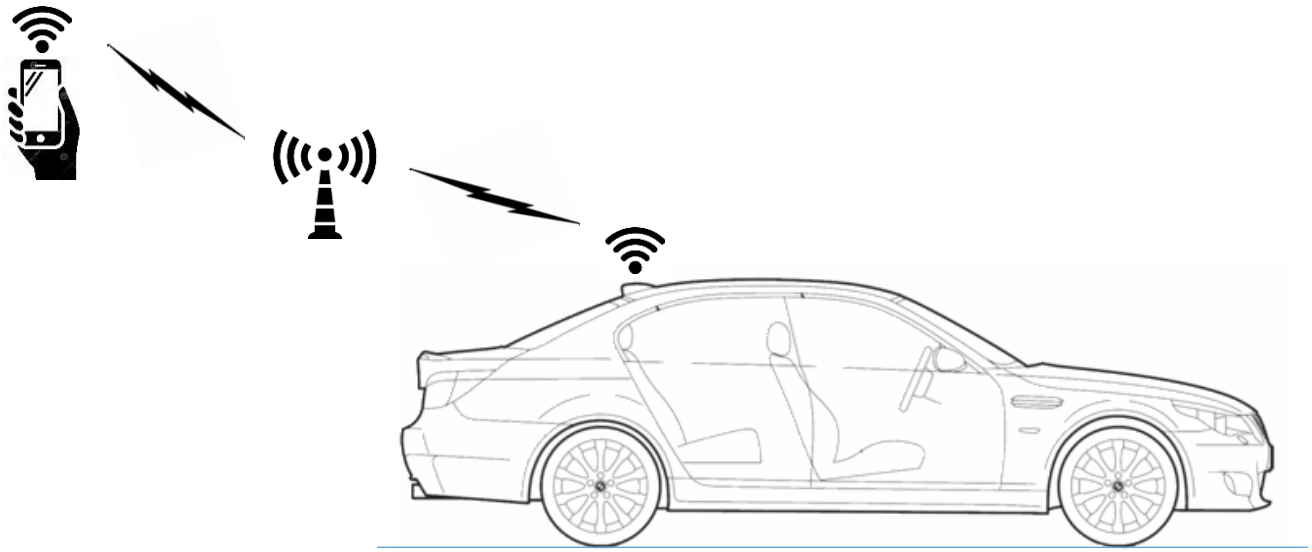
Stakeholders



FBD

Innovation Process – Refine the Design

- Depth sensor locations on curb side of vehicle, in front and rear
  - Individual and average depth; calculates trends for output to screen/phone
- Water sensor locations shown in green. Use in other locations as needed

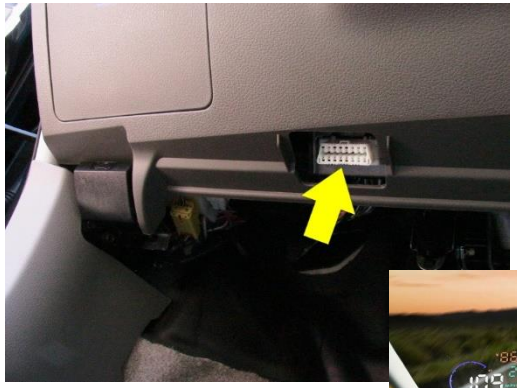


Innovation Process – Alternate Concepts

- Explore other ideas for merit
  - ✓ Inflatable pontoons and propeller drive
  - ✓ 4-wheel jack stands
  - ✓ Car wrap
  - ✓ Range Rover wading
- Study/analyze

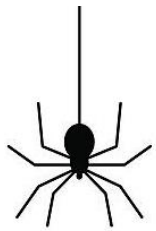
Innovation Process – Spinoffs

- What other stakeholders or users can benefit? Go outside your Context Diagram
  - ✓ Aftermarket (car OBD-2 port)
  - ✓ City rescue vehicles and transportation
  - ✓ Military use

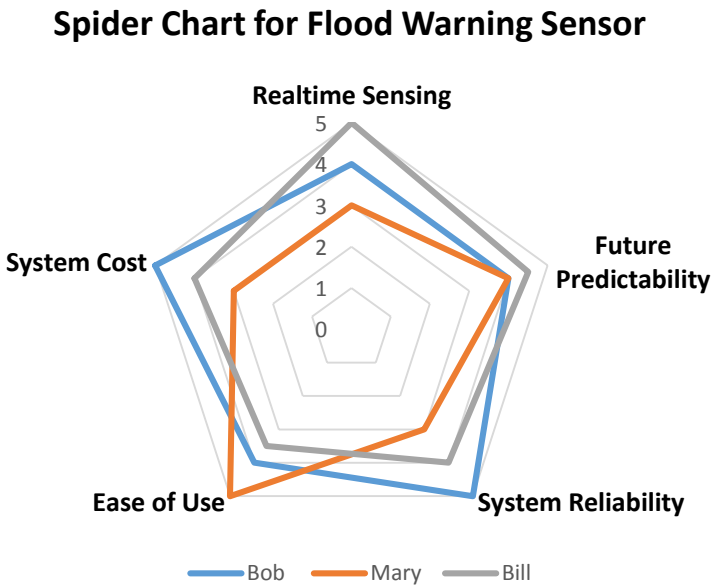


Innovation Process – Driving Attributes

- Select 5-6 spider web or radar chart parameters
  - Accurate water depth sensing
  - Real-time response
  - Predictability of future (trend)
  - Reliability
  - Cost
  - Ease of use

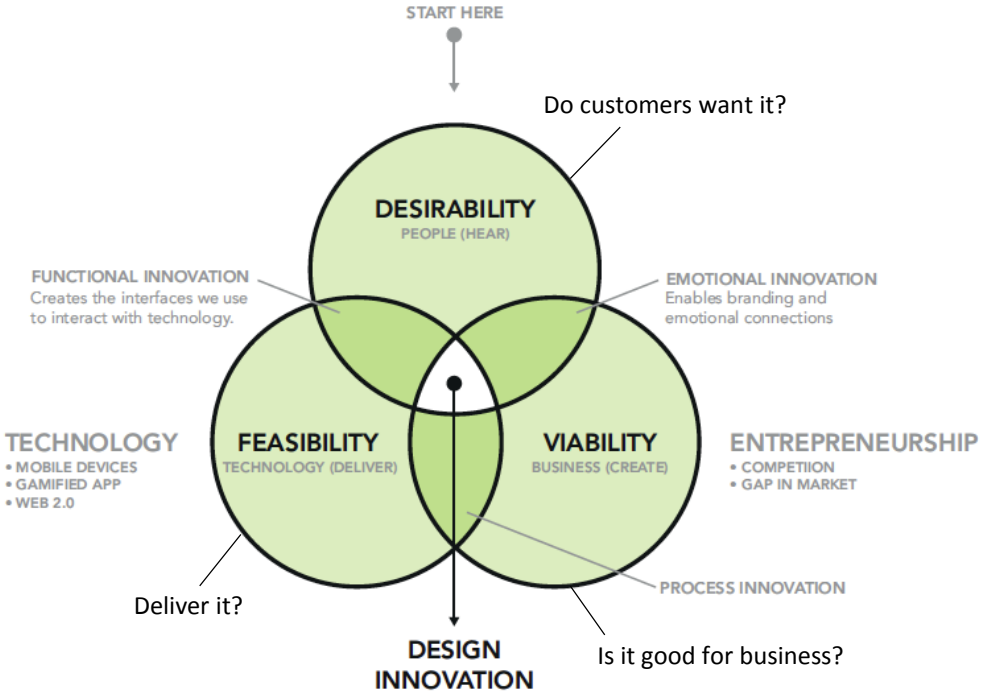


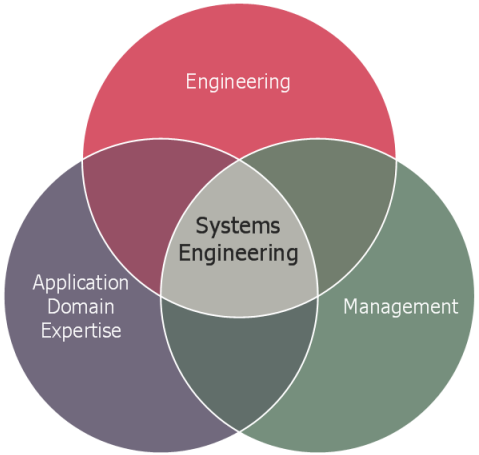
- Mind Map is useful tool also
- Try a Context Diagram
- Maybe a Use-Case Diagram



Innovation Process – Viability

- To find out if the proposed concept will be successful, a Venn diagram can be used, a common tool in Systems Engineering
- Human Centered Design (HCD) is a growing trend

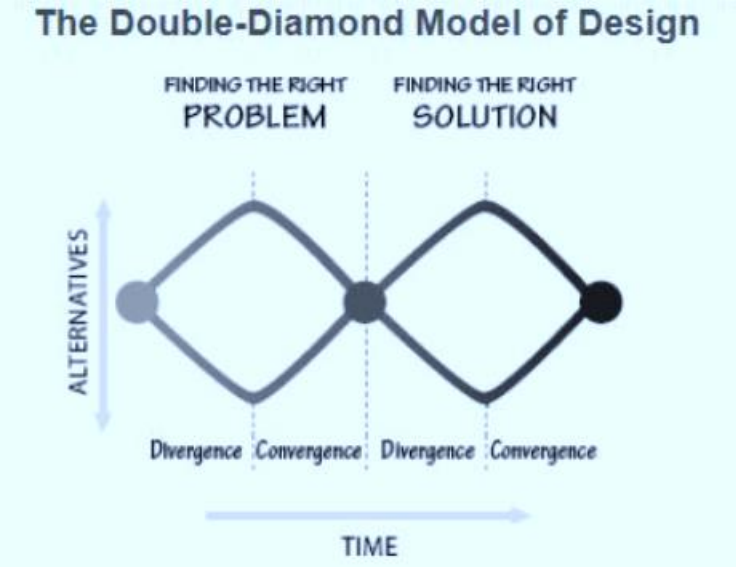


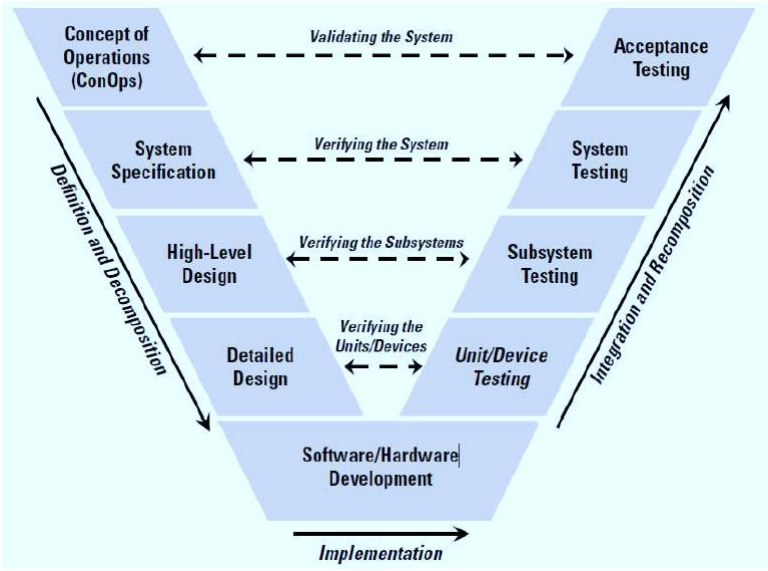


The three "Design Thinking" forces *(people, business, and technology)* are then translated into the three lenses of Human Centered Design *(HCD)*

Innovation Process – Design 'Vergence'

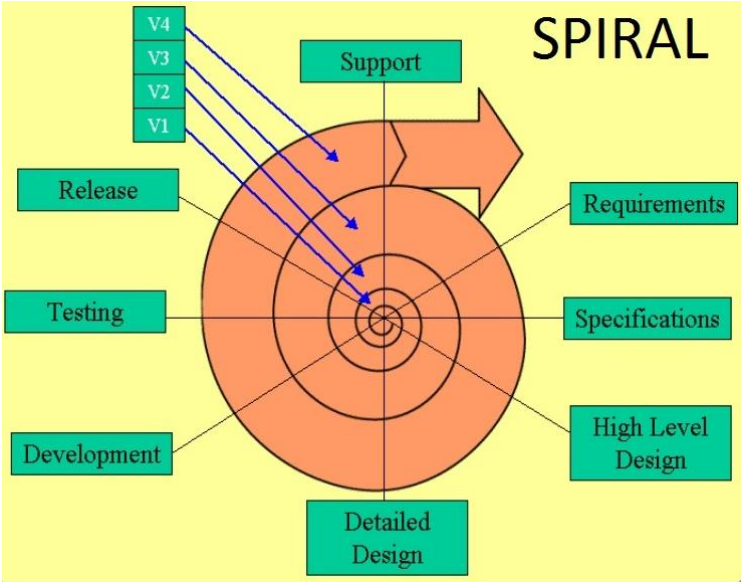
- The Divergence/Convergence method has roots in Systems Engineering as the V-model in terms of Decomposition/Recomposition
- Double-diamond starts with an idea, goes through the initial design research, and expands the thinking to explore fundamental issues
- Only then is it time to converge upon the real, underlying problem
- Finding the solution is the same expansion/contraction





Innovation Process – Early Design Cycle

- Within the Divergence/Convergence the process becomes a human-centered design iteration, aka Spiral Development Method in SE parlance
- Make observations on the intended target, generate ideas, produce prototypes and test them. Repeat until satisfied
- Each iteration makes further progress towards optimization



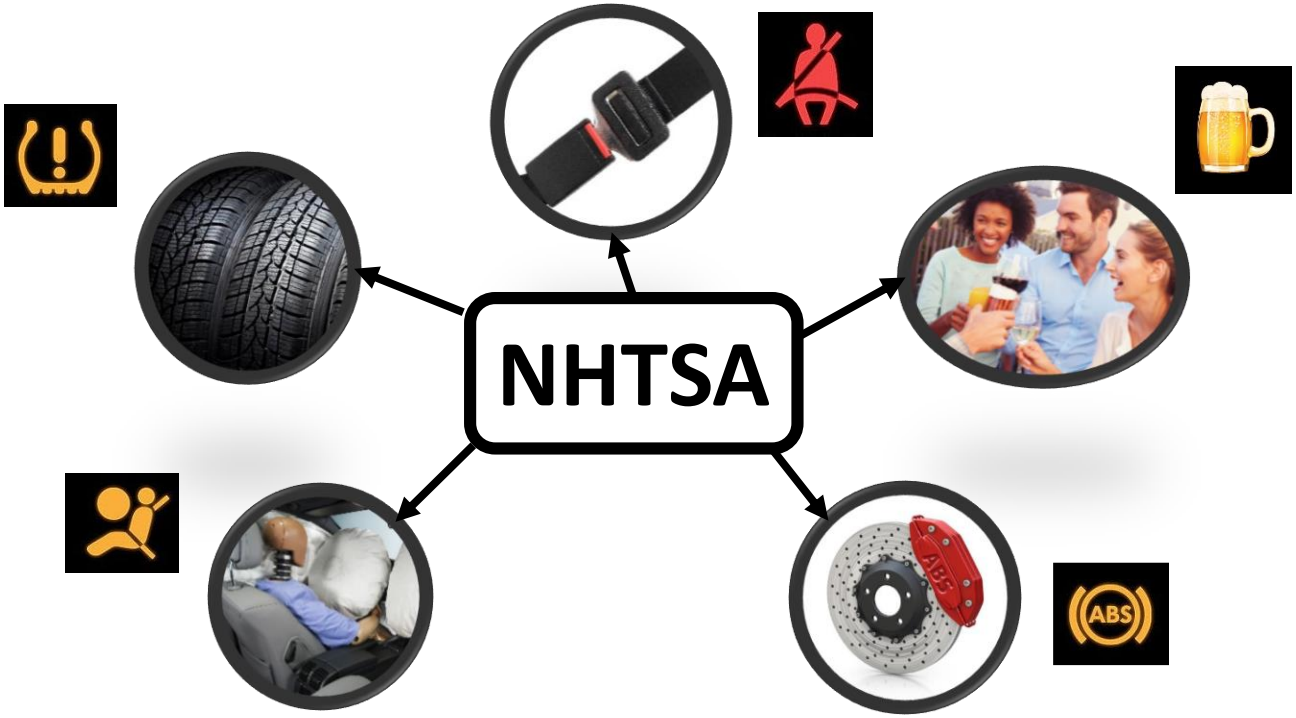
Innovation Process – Patent Search

- How unique and non-obvious is your idea?
  - Research the market
  - Conduct a patent search online
- Easy patent search at Google - https://patents.google.com/
  - Search by key word or patent number
  - Download .pdf files of similar art patents
  - Find your invention classification
  - Read claims of similar patents

- Also can search at the gov site - https://www.uspto.gov/patent
- If you think you have a strong claim and the idea is marketable, file a patent
  - Regular utility patent – legal protection for 20 years from date of file
  - Provisional patent – simple, protected for one year; first to file

Innovation Process – NHTSA Regulations

- What are the current and future safety standards and regulations for cars, governed by NHTSA and DOT?
- Should flood sensing standards be one of them? Vehicles could be rated from a 1-5 scale for flood safety
- New standards could ‘drive’ design improvements by OEMs



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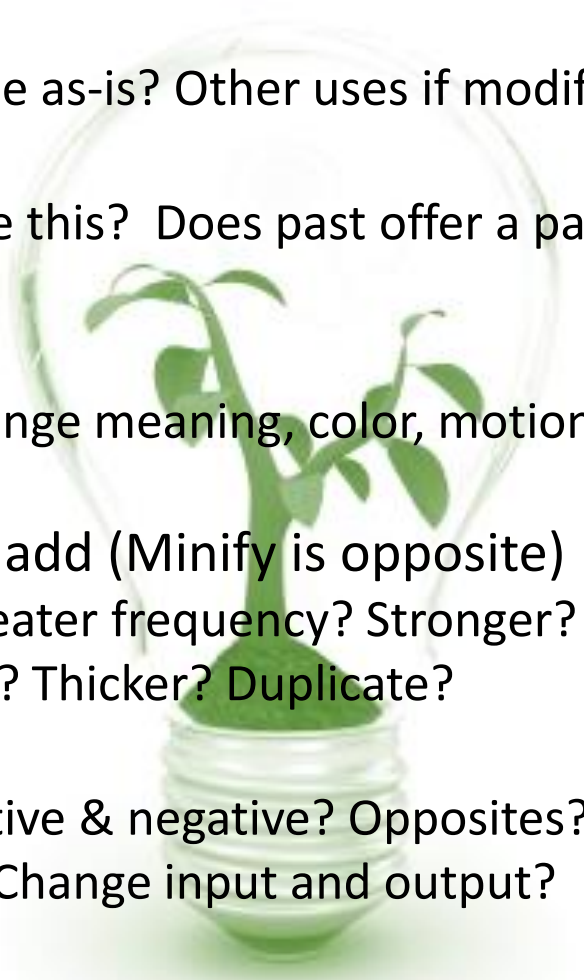
Innovation Process – Creativity

- Think like da Vinci! The original systems thinker…
  - How to Think Like Leonardo da Vinci: Seven Steps to Genius Every Day, by Michael J. Gelb
- The Seven Principals
  - Curiosita – insatiably curious approach to life and an unrelenting quest for learning
  - Dimostazione – the continual refinement of the senses, as the means to enliven experience
  - Sfumato – (literally going up in smoke) a willingness to embrace ambiguity, paradox, and uncertainty
  - Arte/Scienza – the development of the balance between science and art, logic and imagination (whole brain thinking)
  - Corporitalia – the cultivation of grace, ambidexterity, fitness, and poise (balance of body and mind)
  - Connessione – An appreciation for interconnectedness of all things and phenomena (systems thinking)

"Genius is made, not born. And human beings are gifted with an almost unlimited potential for learning and creativity" – back cover of book
*"Think of the end before the beginning" – da Vinci's life code**

Innovation Process – Checklist for New Ideas



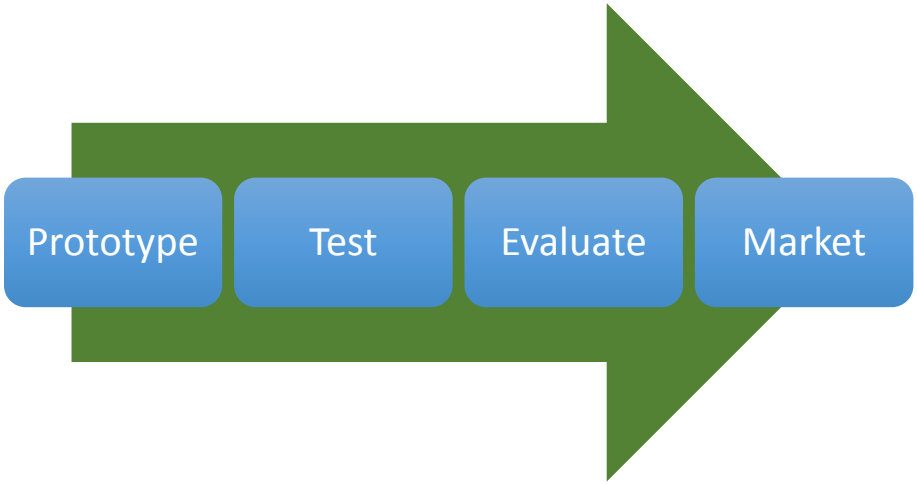
- Put to other uses
  - ✓ New ways to use as-is? Other uses if modified?
- Adapt
  - ✓ What else is like this? Does past offer a parallel? What can you emulate?
- Modify?
  - ✓ New twist? Change meaning, color, motion, sound, odor, form, shape?
- Magnify - What to add (Minify is opposite)
  - ✓ More time? Greater frequency? Stronger? More flexible? Higher? Longer? Thicker? Duplicate?
- Reverse
  - ✓ Transpose positive & negative? Opposites? Turn upside down? Reverse roles? Change input and output?
- Combine
  - ✓ How about a blend, an assortment, or ensemble? Combine units? Combine purposes, or ideas?

Innovation Process – The Explorer's Compass

- Be curious – adopt an "insight outlook"
- Create a map for yourself – have an idea of what you're looking for
- Leave your own turf – look in outside fields, disciplines, and industries
- Too much is not enough – look for lots of ideas
- Don't be afraid to be led astray – you'll find what you weren't looking for
- Break up your routine – use obstacles to get out of ruts
- Shift your focus – pay attention to a variety of information
- Don't overlook the obvious – what's right in front of you?
- What does it all really mean? – stand back and look at the big picture
- Slay a dragon – look for ideas in places you've been avoiding
- Stake your claim – write your idea down when you find it

Innovation Process – Next Steps

- Systems Engineering can and does drive innovation!
- Where do we go from here?



… But that's another story

Backup Charts

Outline of Presentation

- Title
- Scope of discussion
- Phase development
- Problem definition (Harvey)
  - Word Cloud
- Define concept (solution)
  - Sketch
  - FBD
  - Refinement (layout)
  - Alternates
  - Spinoffs
- Review of merits
  - Attributes
  - Viability
- Synthesis
  - ‘Vergence’
  - Spiral development
- Further Steps
  - Patent Search
  - Regulations
  - Consult Expertise
- Pushing Creativitiy
  - Da Vinci – 7 Principles
  - Checklist
  - Explorer’s Compass
- Next Steps