WELCOME!

INCOSE Enchantment Chapter Monthly Meeting

We’re glad you’re here.

We respectfully request:

- Mute your audio when you are not speaking
- *6 toggle or in GlobalMeet left-side, your name

Discussion and questions are encouraged!

Put questions in the chat box or unmute yourself to speak up.

Meeting Materials

Slide presentations can be downloaded prior to start of the meeting from the Meeting Materials page of our website:

https://www.incose.org/incose-member-resources/chapters-groups/ChapterSites/enchantment/resources/meeting-materials

If recording is authorized by speaker, the video will be posted at the link above within 24 hours.

SEP Training

CSEP Courses by *Certification Training International:*

CTI currently is offering online course offerings, see https://certificationtraining-int.com/incose-sep-exam-prep-course/

Our chapter has two SEP mentors:

Ann Hodges alhodge@sandia.gov

Heidi Hahn drsquirt@outlook.com

Upcoming meetings

- June 9, 2021: Paul Davies, Interface Management – The Neglected Orphan of Systems Engineering
- July 14, 2021: Dr. Dave Peercy, Education as a System of Systems
- August 11, 2021: Pat Foley, WBS Integration with an Effective Schedule
- September 8, 2021: Brian Kennedy, Leveraging Set-Based Practices to Enable Efficient Concurrency in Large Systems and Systems-of-Systems Engineering

Introductions

- Please type your name, position, and organization in the Chat window

Photo by Adam Solomon on Unsplash

Survey

The link for the online survey for this meeting is

- www.surveymonkey.com/r/2021_05_MeetingEval

Your feedback is important!

Enchantment Chapter Monthly Meeting

Human Systems Integration and Its Role in Systems Engineering

Abstract: This talk will provide an overview of human physical, perceptual, and cognitive capabilities how they can be addressed and integrated within systems. Embedding human systems integration within Systems Engineering ensures more efficient and effective systems, tools and machines by matching the system to the known human abilities and limitations. More specifically, the following questions will be addressed: What is human systems integration? What is human centered-design? And what considerations should a system's engineer take to ensure the human has been adequately addressed across a projects lifecycle?

Download recording from the Library at www.incose.org/enchantment

NOTE: This meeting will be recorded

Speaker Bio

Dr. Cheryl Bolstad is a Principal Systems Research and Analysis Engineer for the Applied Cognitive Science department at Sandia National Laboratories in Albuquerque, NM. Dr. Bolstad is a Certified Professional Ergonomist and has a Ph.D. in Psychology specializing in cognition and human factors from North Carolina State University. Dr. Bolstad has over 30 years of experience working with the Department of Defense and the commercial sector as a human factors engineer. She has worked extensively in situation awareness (SA) research, human automation integration, user interface design, team training and performance. During her career Dr. Bolstad has worked on projects for military weapons programs, military and commercial aviation, US Center for Disease Control, emergency medical response operations, military health services, regional power companies, commercial automakers and several large computer and technology corporations. Currently, Dr. Bolstad is on the Enchantment Chapter board of directors and is the National Membership Committee Chair for the Human Factors and Ergonomics Society. Dr. Bolstad has authored over 100 publications, is a member of multiple professional organizations and serves as a professional reviewer for many international journals

Human Systems Integration and Its Role in Systems Engineering

Cheryl Bolstad PhD, CPE

I would like to thank Paul Schutte Org 6672 for his slides on human information processing

Outline

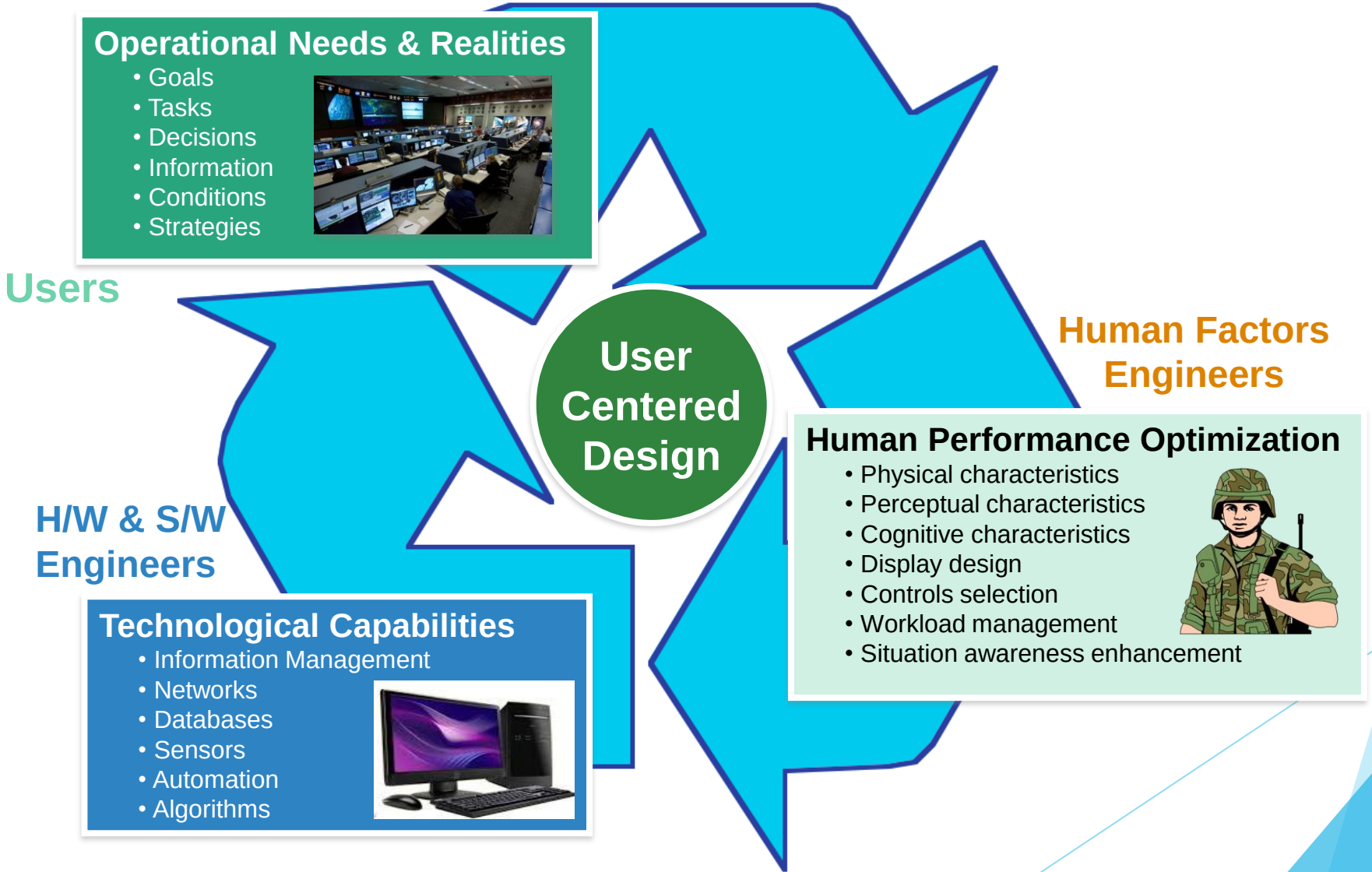
- What is human systems integration?
- What is human centered-design?
- What considerations should a system's engineer take to ensure the human has been adequately addressed across a projects lifecycle?
  - About Humans
  - About Human Centered Designs
  - Testing the Human Aspect

Human Systems Integration

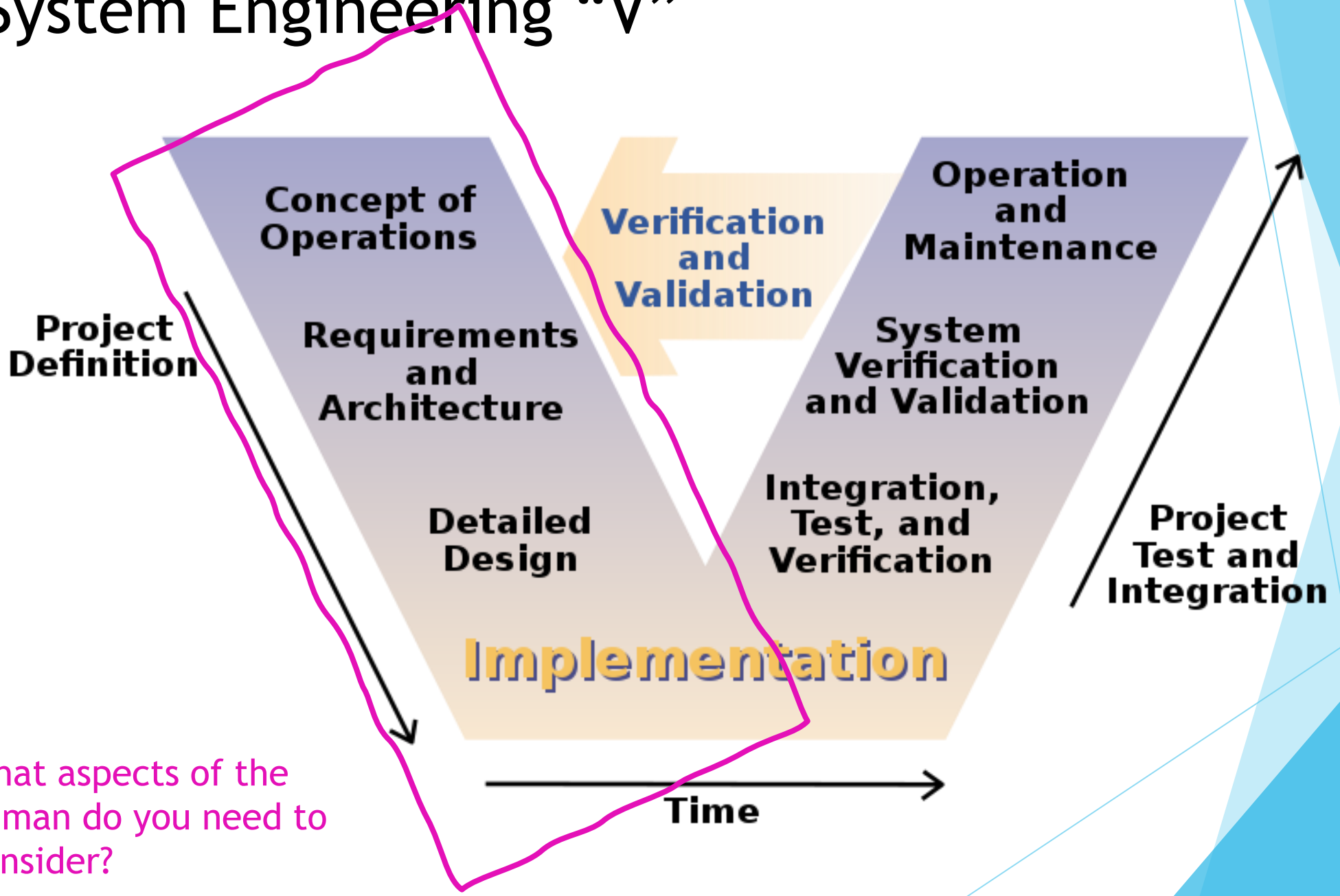
- INCOSE:
  - Interdisciplinary technical and management processes for **integrating human** considerations within and across all **system** elements; an essential enabler to systems engineering practice.
  - **G**rowing practice derived from the conjunction of **Human-Centered Design (HCD)** and Systems Engineering (SE). HSI puts people at the center of the design

- Other Names:
  - HF
  - UCD
  - UI
  - HMI

Human-Centered Design = Effective Human Machine Integration



System Engineering “V”

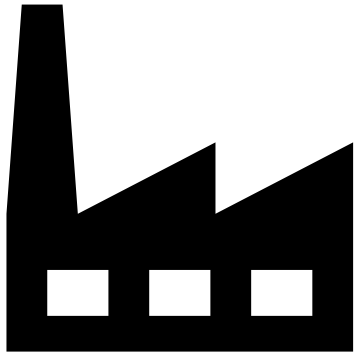


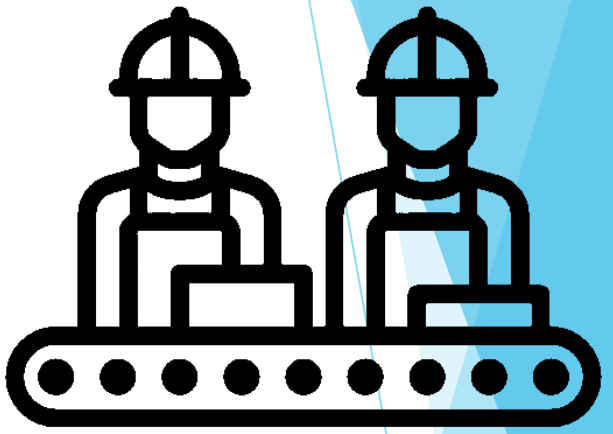
What aspects of the human do you need to consider?

What if my system doesn't involve a human?

What if my system doesn’t involve a human?

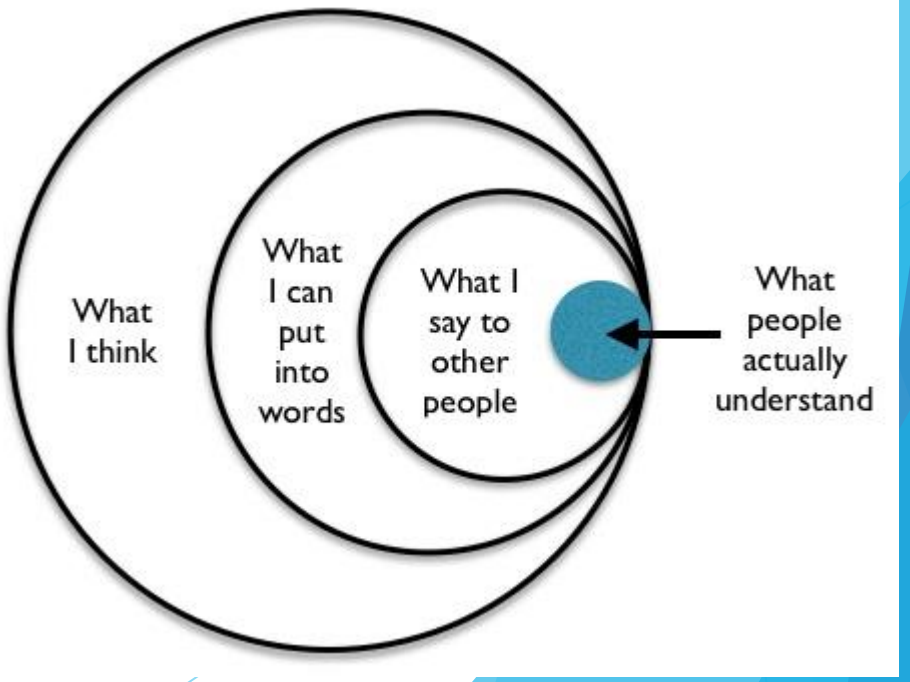
- Is it manufactured?
- Is it assembled?
- Is it transported?
- Is it maintained?
- Chances are – humans are involved.





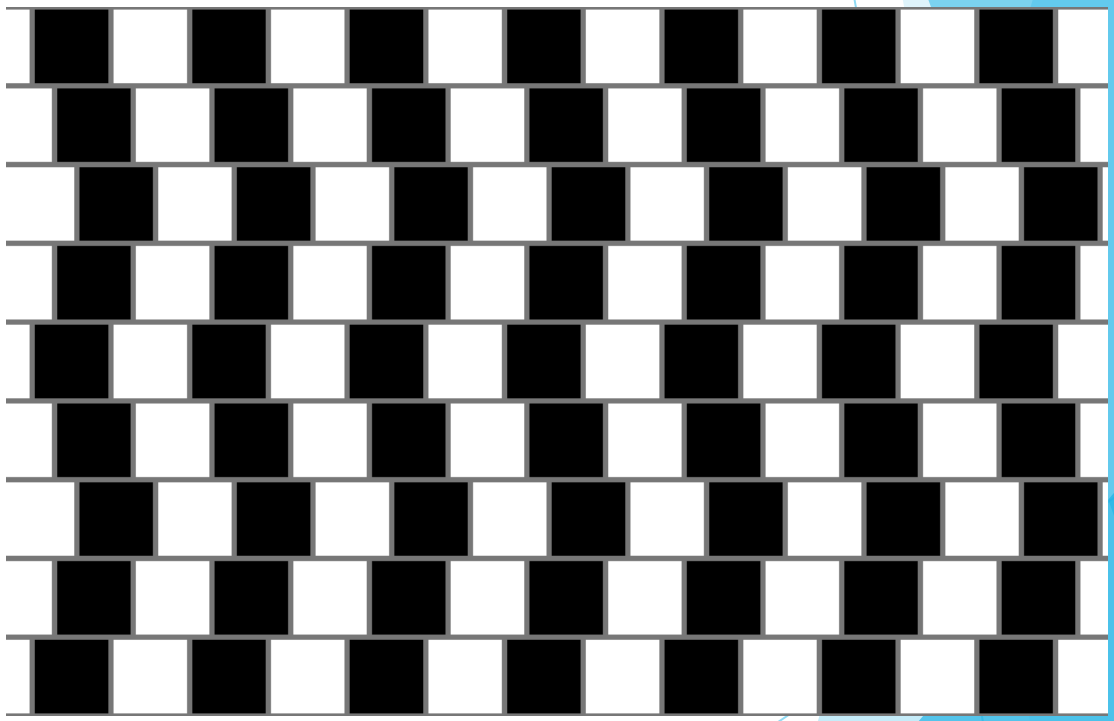
Humans Are Messy!

- Follow the path of least resistance
- We tend to overestimate how many people share our choices, values, and judgments (so we can not design for ourselves)
- Ability to adapt to even the worse designs
- Huge variability in the general population
- It is impossible to ensure that all future system users will have the “same” physical abilities or mental skill level.



Humans are bad at:

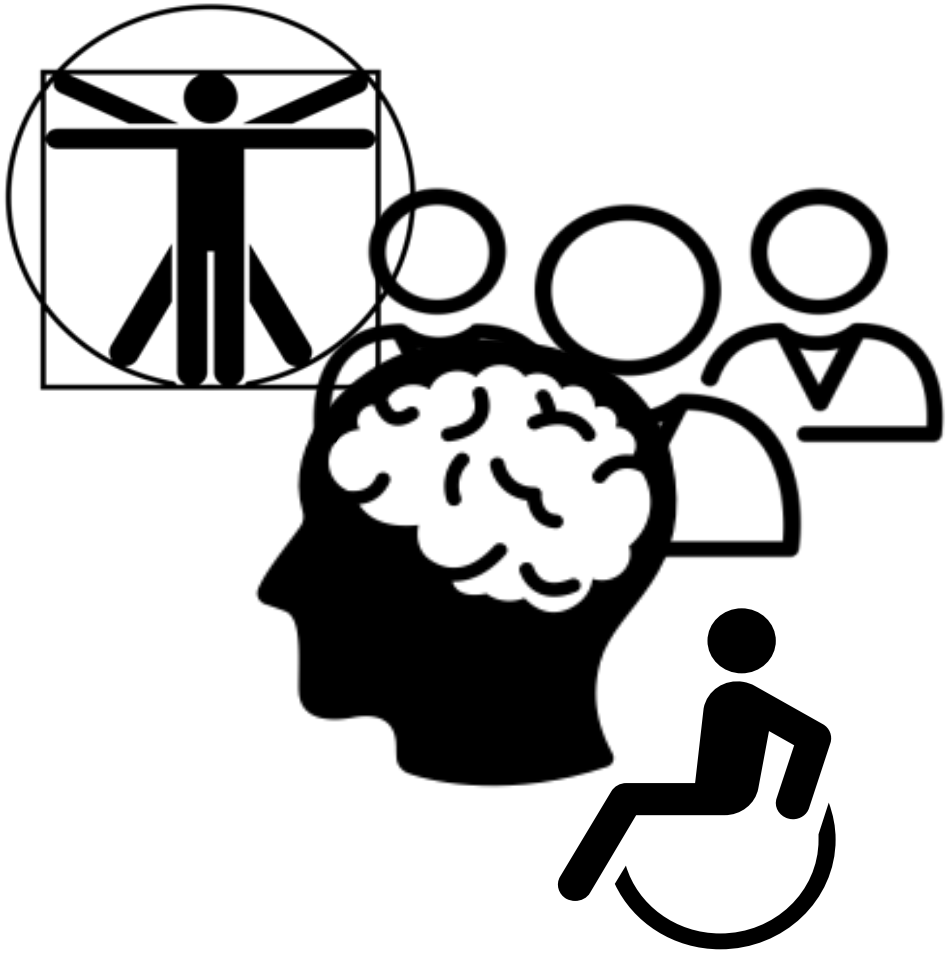
- Probability (51% == 100%)
- Future planning (X therefore Y)
- Specific recall (password123)
- Judgments of themselves and others (I’m better than Steve)
- Vigilance
- Complexity (7/2 recall)
- And much more



Humans are good at:

- Creative – find new ways to use things
- Adaptive – even to poor designs
- Goal Driven – want to succeed
- Multipurpose
- Multimodal – very good at using multiple senses at the same time
- Teachable
- Efficient
- Empathetic
- Intuition
- Will-to-Live

Humans



- Physiological abilities
- Anthropometrics
- Sensation and Perception
- Cognitive Processes
- Mental Models
- Errors and biases
- Individual Differences
- Environmental Impacts
- Technology Impacts
- Organizational Impacts

Parameter	Mean	Range
Eye movement time	230 ms	70-700 ms
Decay half-life of visual image storage	200 ms	90-1000 ms
Visual Capacity	17 letters	7-17 letters
Decay half-life of auditory storage	1500 ms	90-3500 ms
Auditory Capacity	5 letters	4.4-6.2 letters
Perceptual processor cycle time	100 ms	50-200 ms
Cognitive processor cycle time	70 ms	25-170 ms
Motor processor cycle time	70 ms	30-100 ms
Effective working memory capacity	7 chunks	5-9 chunks
Pure working memory capacity	3 chunks	2.5-4.2 chunks
Decay half-life of working memory	7 sec	5-226 sec
Decay half-life of 1 chunk working memory	73 sec	73-226 sec
Decay half-life of 3 chunks working memory	7 sec	5-34 sec

Rough Baselines of Human Physiological Abilities

- Rough numbers
- Individual differences (range)
  - Expand with age
  - Not really traimable

Anthropometry

- Anthropometry is the study of the measurements and proportions of the human body.
- Range of variability for many structural body dimensions is considerable – even within a “homogeneous population”
- For design, variability in physical dimensions is expressed in terms of percentiles which are based on normative data for a given population
- “Average” applies only to groups, not individuals
- Variability can be addressed through:
  - Customized design
  - Adjustability
  - Designing for the (mythical) average
  - Designing for the range (5^{th}/95^{th} percentiles) of users

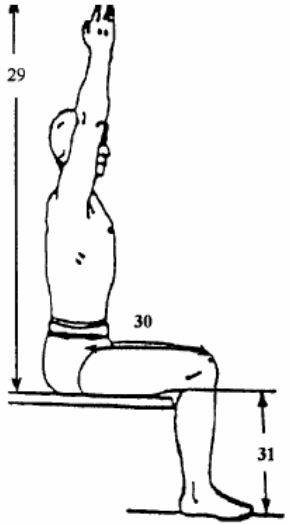
Questions Anthropometry can help answer…

- At what height should a control knob be mounted?
- How big does a maintenance access panel need to be to allow a technician to do work using a screwdriver?
- What is the minimum amount of crawl space under a machine to allow access by required personnel?

Anthropometric Data

- Source: Ahlstrom, V. & Longo, K. (2003). Human factors design standard (HF-STD-001), Chapter 14: Anthropometry and Biomechanics. Atlantic City International Airport, NJ: Federal Aviation Administration

Exhibit 14.3.2.1 (continued) Static human physical characteristics (seated)

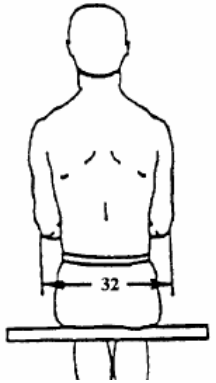


29 Vertical Reach, Sitting. The vertical distance from the sitting surface to the tip of the middle finger, measured with the subject sitting and the arm, hand, and fingers extended vertically.

			Percentiles				
	Sample		1st	5th	50th	95th	99th
A	Men	cm	129.3	133.8	143.3	153.2	156.7
		(in)	(50.9)	(52.7)	(56.4)	(60.3)	(61.7)
B	Women	cm	119.7	123.3	132.7	141.8	145.4
		(in)	(47.1)	(48.5)	(52.2)	(55.8)	(57.2)

30 Abdominal Depth, Sitting. The depth of the abdomen, with the subject sitting.

			Percentiles				
	Sample		1st	5th	50th	95th	99th
A	Men	cm	18.6	19.9	23.6	29.1	31.4
		(in)	(7.3)	(7.8)	(9.3)	(11.5)	(12.4)
B	Women	cm	17.3	18.5	21.9	27.1	29.5
		(in)	(6.8)	(7.3)	(8.6)	(10.7)	(11.6)



31 Popliteal Height, Sitting. The vertical distance from the footrest surface to the underside of the lower leg, measured with the subject sitting.

			Percentiles				
	Sample		1st	5th	50th	95th	99th
A	Men	cm	37.8	39.5	43.3	47.6	49.5
		(in)	(14.9)	(15.6)	(17.0)	(18.7)	(19.5)
B	Women	cm	33.7	35.1	38.9	42.9	44.6
		(in)	(13.3)	(13.8)	(15.3)	(16.9)	(17.6)

Anthropometric Data

KNOB DIAMETER (INCHES)	KNOB DEPTH (INCHES)			
	FINGER GRIPPED 		FULL-HAND GRIPPED 	
	0.50	1.0	0.50	1.0
0.50	5 in. lb	6 in. lb	11 in. lb	16 in. lb
0.75	6 in. lb	8 in. lb	20 in. lb	29 in. lb
1.00	8 in. lb	10 in. lb	5 ft lb	6 ft lb
1.50	13 in. lb	15 in. lb	7 ft lb	10 ft lb
2.00	20 in. lb	24 in. lb	11 ft lb	13 ft lb
3.00	6 ft lb	6 ft lb	14 ft lb	16 ft lb

TURNING HAND STRENGTH

Source: Woodson, W.E., Tillman, B., & Tillman, P. (1992). Human factors design handbook: information and guidelines for the design of systems, facilities, equipment, and products for human use. San Francisco, CA: McGraw- Hill Inc.

Sensation and Perception

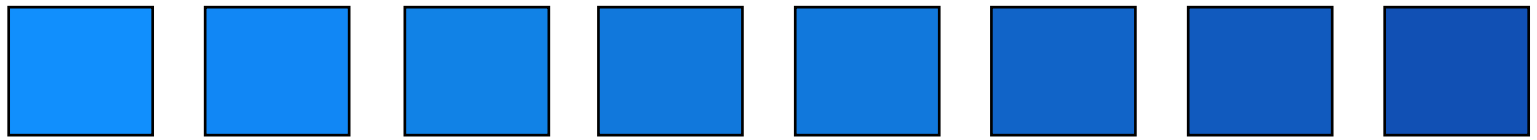
Stimuli → Sensory Register → Perception

Sensation and Perception

- Receptors convert stimuli into electrochemical energy that is processed in the brain
- Perception involves more than the receipt of sensory information
  - We must attend to, select, organize, and interpret this information in order to meaningfully recognize objects and events in our environment.
- Not all stimuli provide the same amount of “information”
- Sensitivity of stimuli varies among individuals

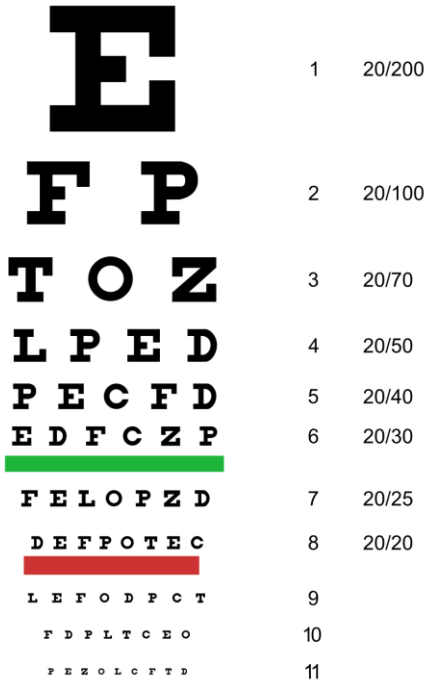
http://agenheimer.com/psychology/psychs-p

Do you see a difference?

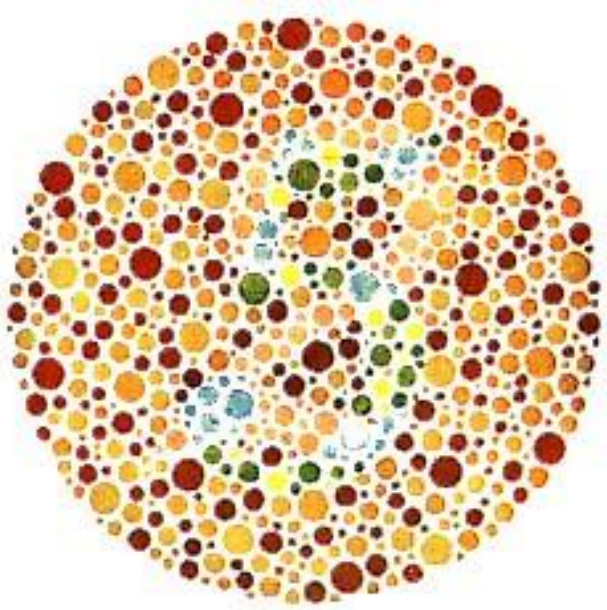


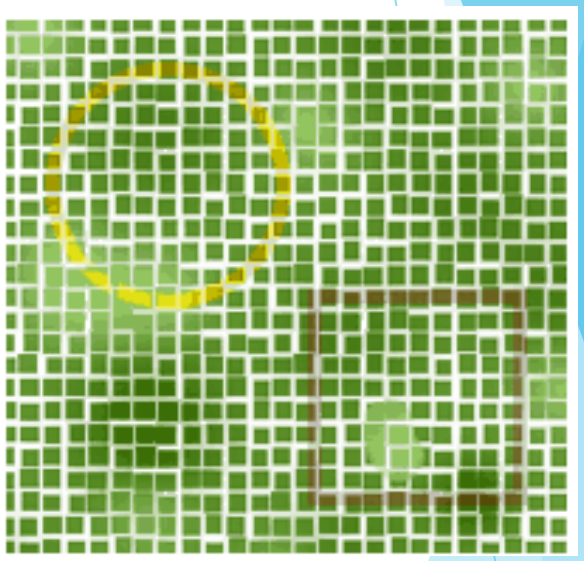
Stimuli → Sensory Register → Perception

Visual Acuity and Color Perception



Snellen Eye Chart

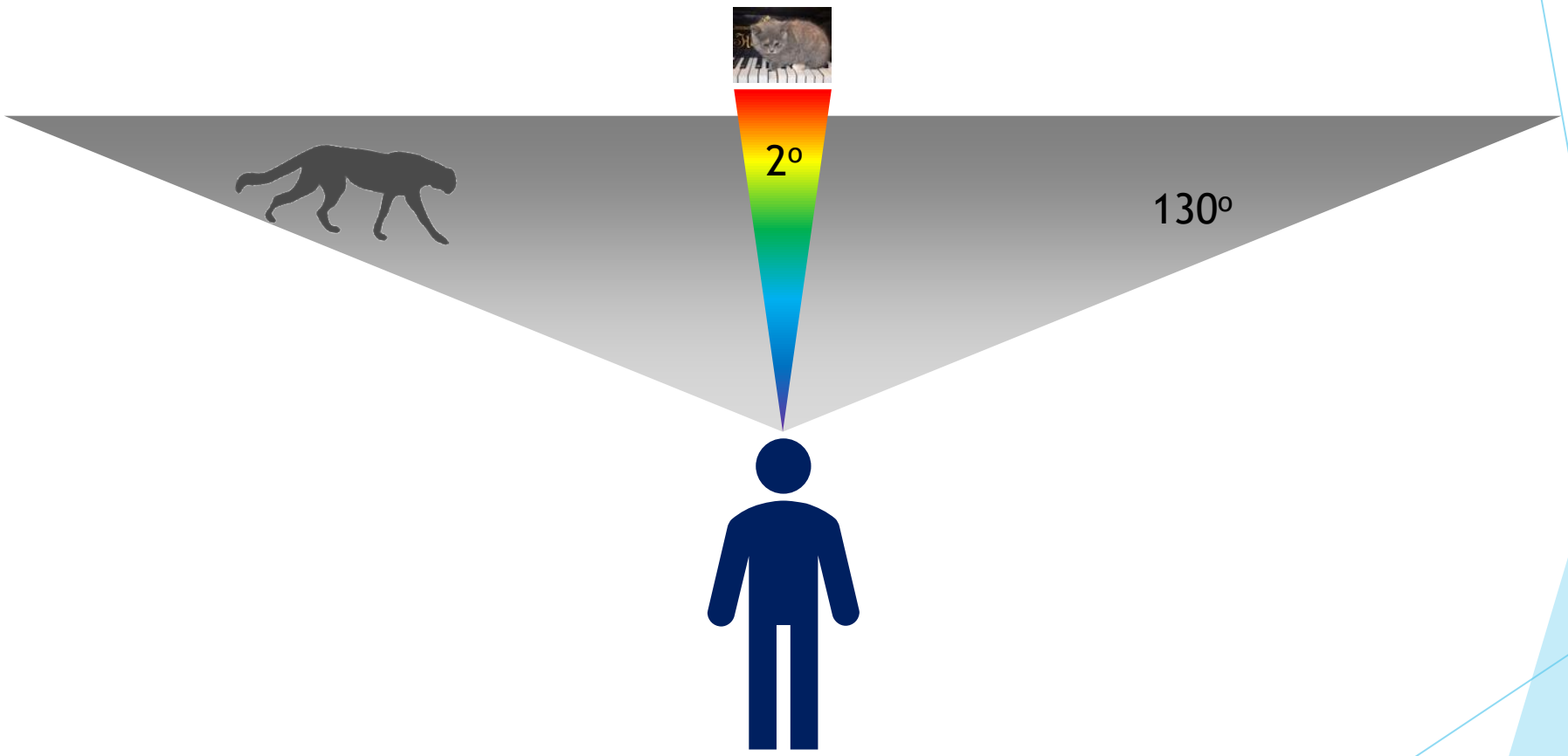




6-10% of males have some form of red/green color blindness

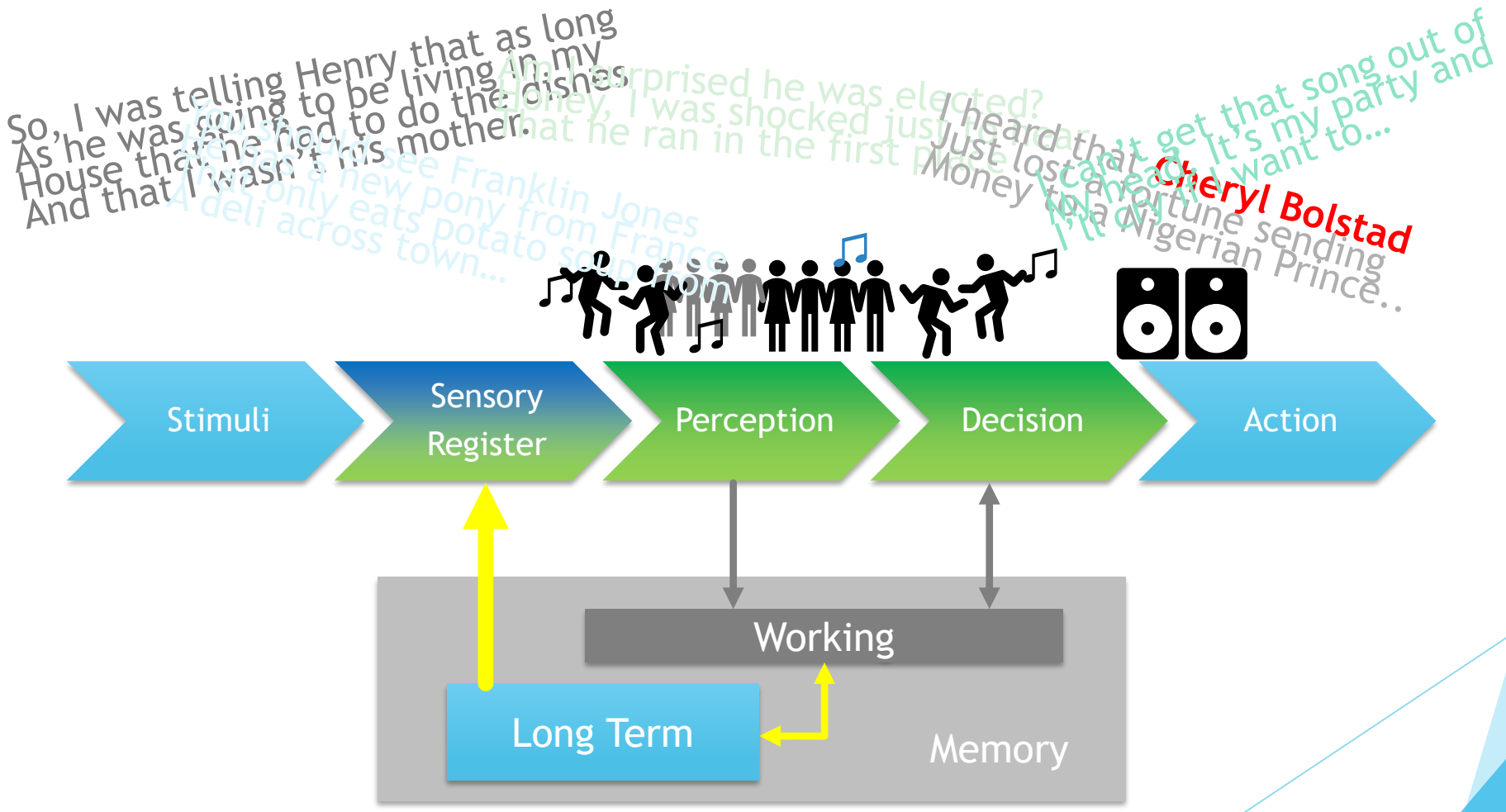
Stimuli → Sensory Register → Perception

Peripheral vs. Foveal Vision



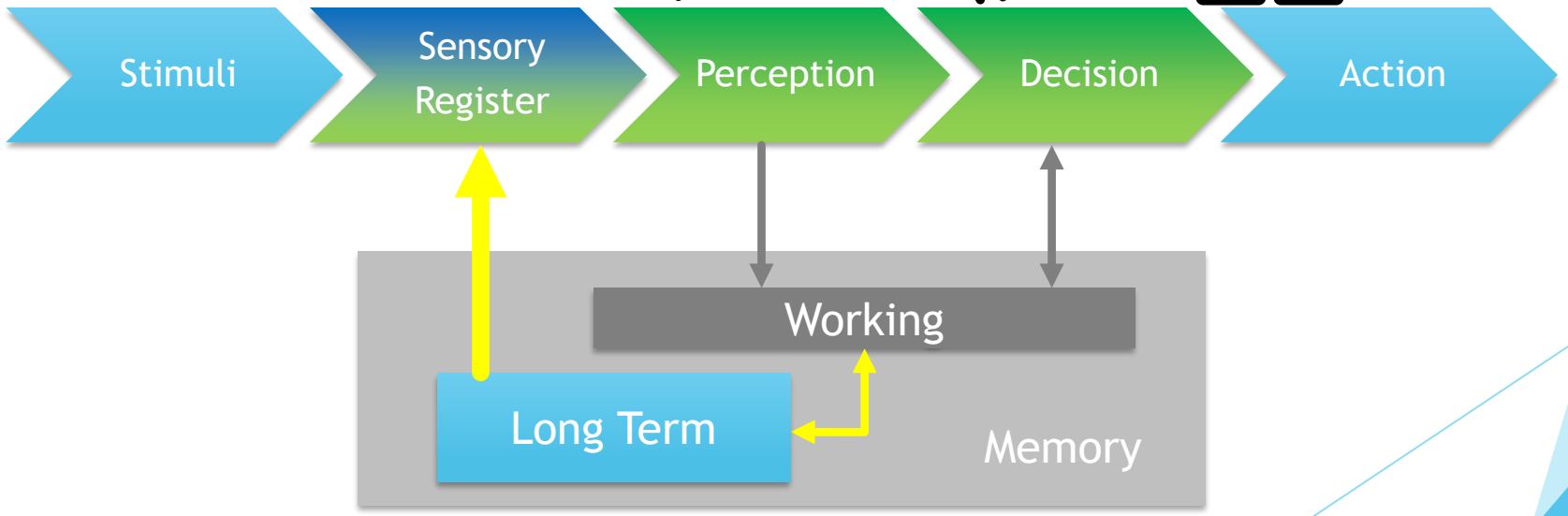
Stimuli → Sensory Register → Perception

Sensation and Perception



Sensation and Perception

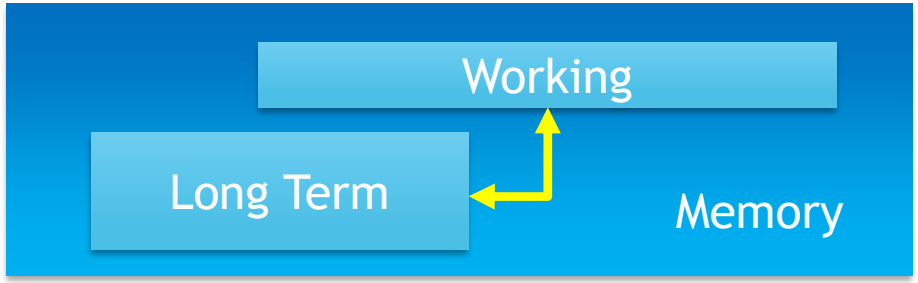
I heard that **Cheryl Bolstad**
Just lost a fortune sending
Money to a Nigerian Prince..



Cognitive Processes/ Memory

Short Term or Working Memory

- Gone in seconds without rehearsal
- Limits on working memory are 7 ± 2
  - Chunking
  - 7 things: 0 – 0 – 1 – 1 – 1 – 2 – 9
  - 2 chunks: 911 (emergency) 2001 (year)
  - 1 chunk: 911 2001 (terrorist attack)

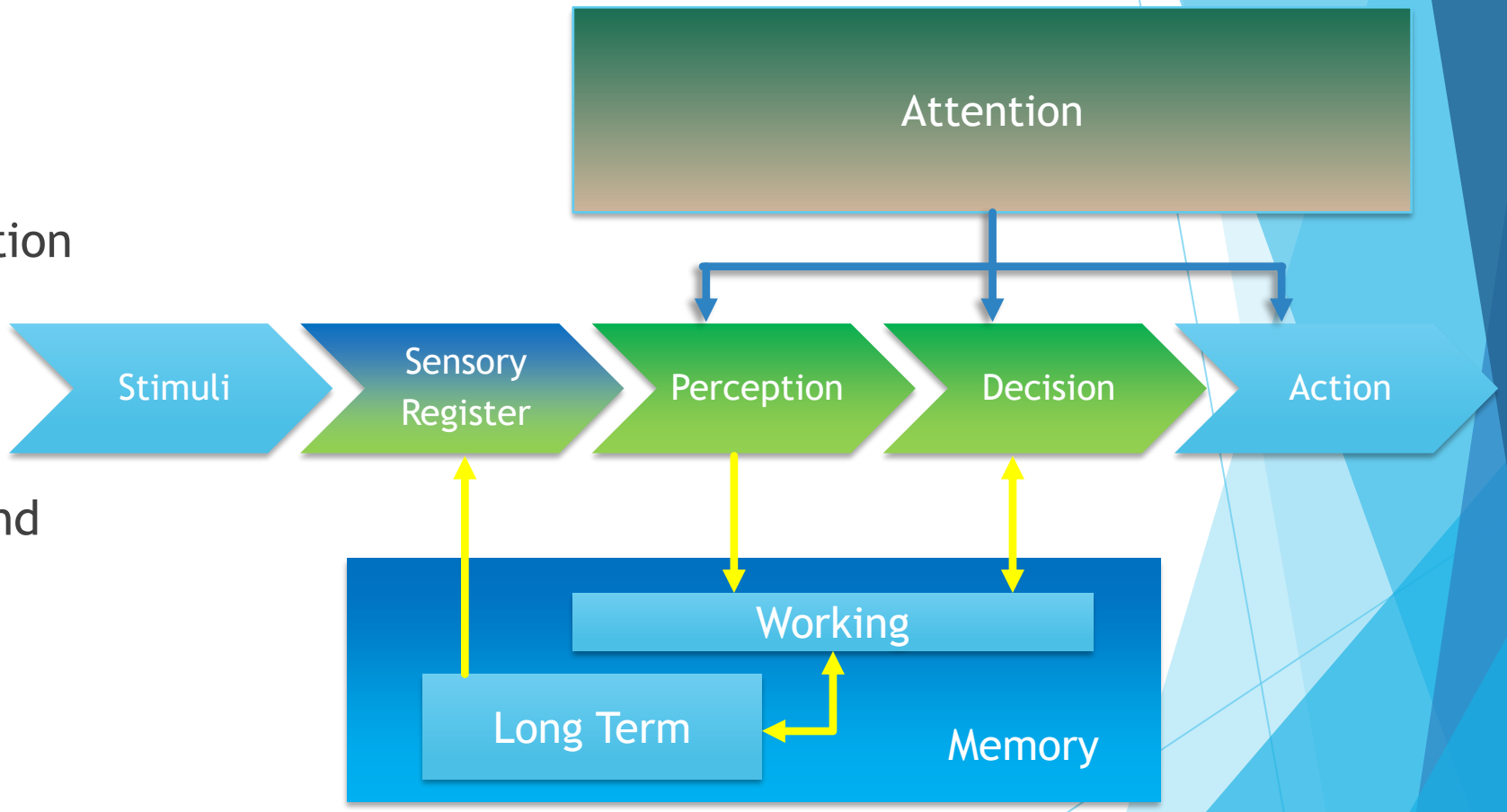


Long Term Memory

- Virtually limitless – But you don't remember everything you experience
- Far from veridical
- Recall methods are variable – recreation and fill in the blanks
- Types:
  - Declarative, Retrospective, Procedural, Prospective
- HIGHLY dependent on attention

Cognitive Processes/ Attention

- Attention is the allocation of information processing capacity
- Perception, decision-making, memories, and action can't occur (consciously) without Attention.



Cognitive Processes/ Attention: Real World Example

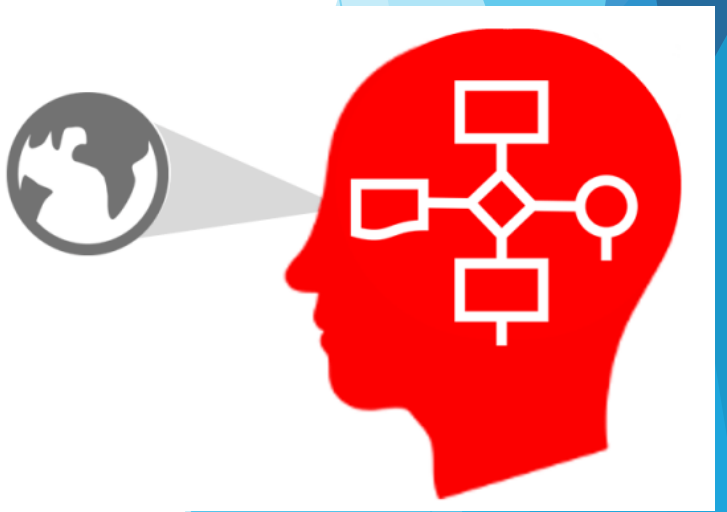
- On September 12, 2008, a freight train and a commuter train collided head-on in Chatworth, CA
- 25 people were killed
- National Transportation Safety Board determined that the commuter train engineer was distracted by text messaging when the accident occurred

Mental Models

- What the user believes about the system at hand
- Problems with that:
  - Belief not facts (Lets hope they are right)
  - Individualized (Theirs not yours)
  - Highly sensitive to:
    - Memory
    - Expectations
    - Perspective

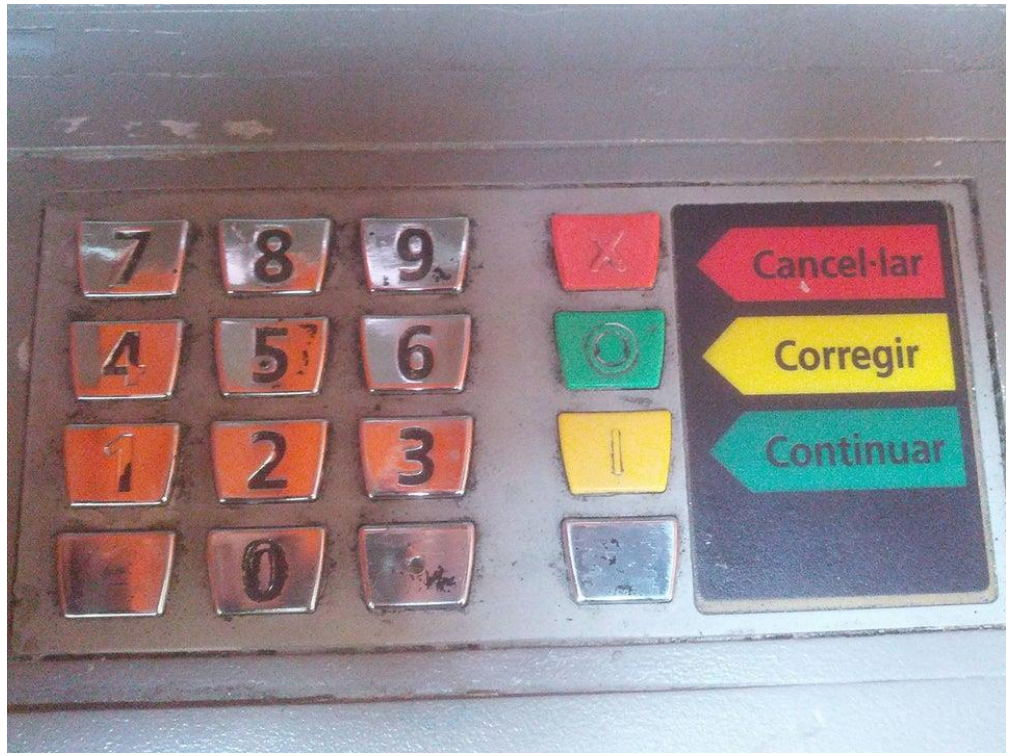
A **mental model** is:
'an explanation of someone's thought process about how something works in the real world'.

Wikipedia



Mental Models

How Does This Work (ATM)?

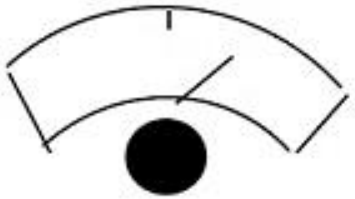


How Does This Work (Push or Pull)?

Errors and Biases

- Attribution Asymmetry
  - Human's tendency to attribute success to internal characteristics and to attribute failures to external factors. Interestingly, the reverse is true when evaluating the success of others.
- The Confirmation Bias
  - Humans seek and thus find information that confirms their chosen hypothesis and avoid information that refutes it.
- The Salience Bias
  - The tendency to choose the easiest-to-understand answer, the most interesting item, or the option that is most striking or visible.
- Group Think
  - Peer pressure. When an individual feels compelled to adhere to opinions held by a larger group.

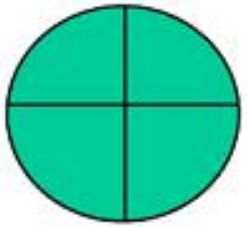
Population Stereotypes



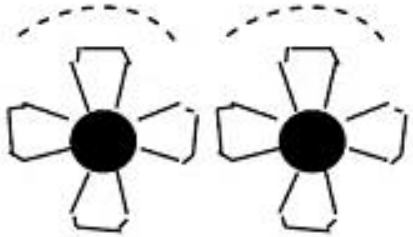
Knob

1. To move the arrow-indicator to the center of the display, how would you turn the knob?

_____ clockwise
_____ counterclockwise



2. In what order would you label the 4 quadrants of a circle. Write in the letters A, B, C, D, assigning one letter to each Quadrant.



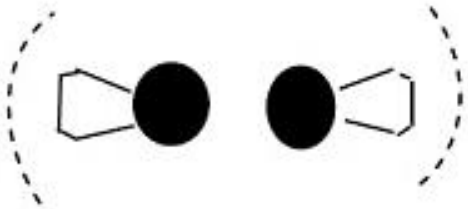
3. Here are 2 knobs on a bathroom sink, looking down at them. Put an arrow on each dotted line, to show how you would use them to turn the water on.

4. Here is a river flowing from east to west. Is the house on the

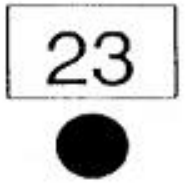
_____ left bank?
_____ right bank?

5. To move the arrow indicator to the right of the display, how would you move the lever?

_____ Push
_____ Pull



6. Here are two knobs on a bathroom sink, looking down on them. Put an arrow on each dotted line, to show how you would operate them to turn water on.



7. To increase the number in the displayed window, how would you turn the knob?

_____ clockwise
_____ counterclockwise

Individual Differences

- Do not design for you – as you are not user
- Individuals vary in terms of vision, size, strength, memory, biases, experience etc.
- No two people are the same
- When collecting requirements gather user/human requirements from multiple source

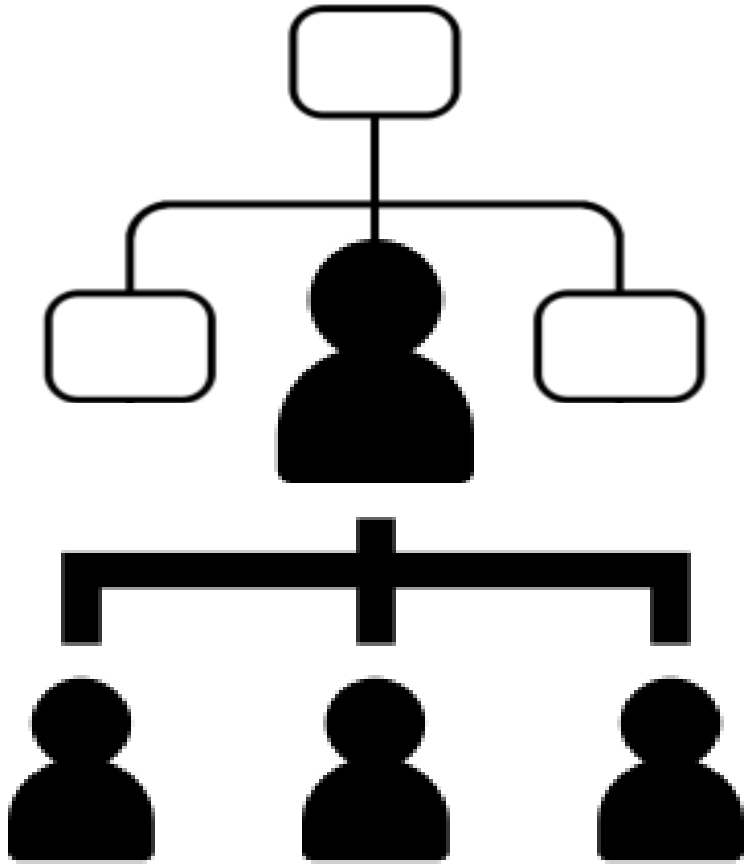
Environment

- Temperature
- Noise
- Lighting
- Distraction
- Work layout
- Access to tools
- Access to information
- Ergonomics

Technology

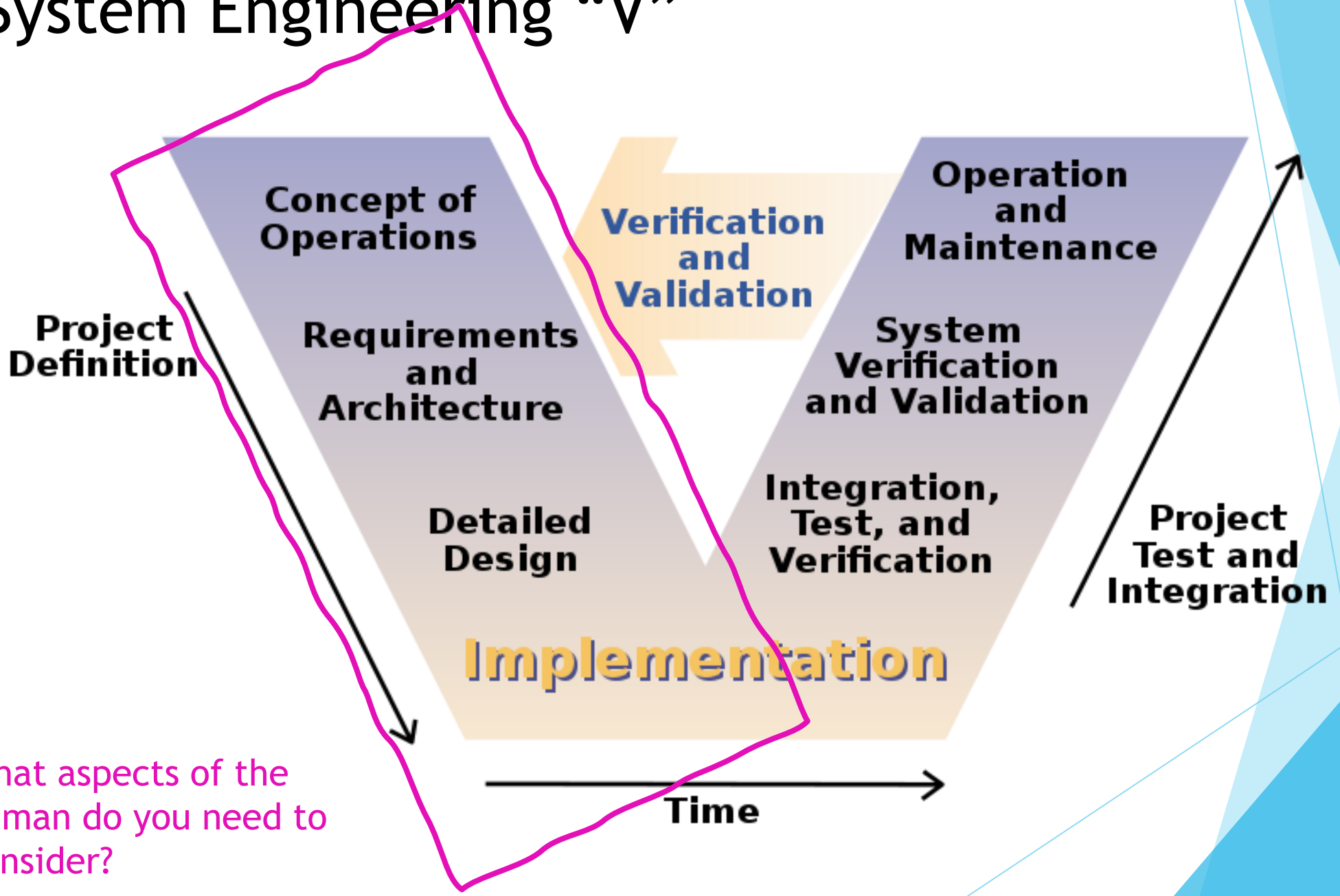
- Interfaces
- Usability
- Function allocation
- Human-Machine teaming
- Transparency and explainability
- Trust

Organization



- Organizational pressures
- Communication
- Information sharing
- Common goals & expectations
- Bureaucracy & ‘red tape’
- Chain of command
- Teaming

System Engineering “V”



What aspects of the human do you need to consider?

Systems Requirements and HSI

- Where do we begin?
- Determine the system requirements to ensure optimal human system integration.
- Remember to include the human operator/user/maintainer/manufacturer and transporter!
- There are multiple types of requirements and methods for collecting these requirements
- Gathering and assessing human-system requirements
  - Human-Systems Requirements
  - Task Analysis
  - Human-Machine Function Allocation

Task Complexity

System Layout

Task Distribution

Task Loading

Level of Automation

Human AI Tasking

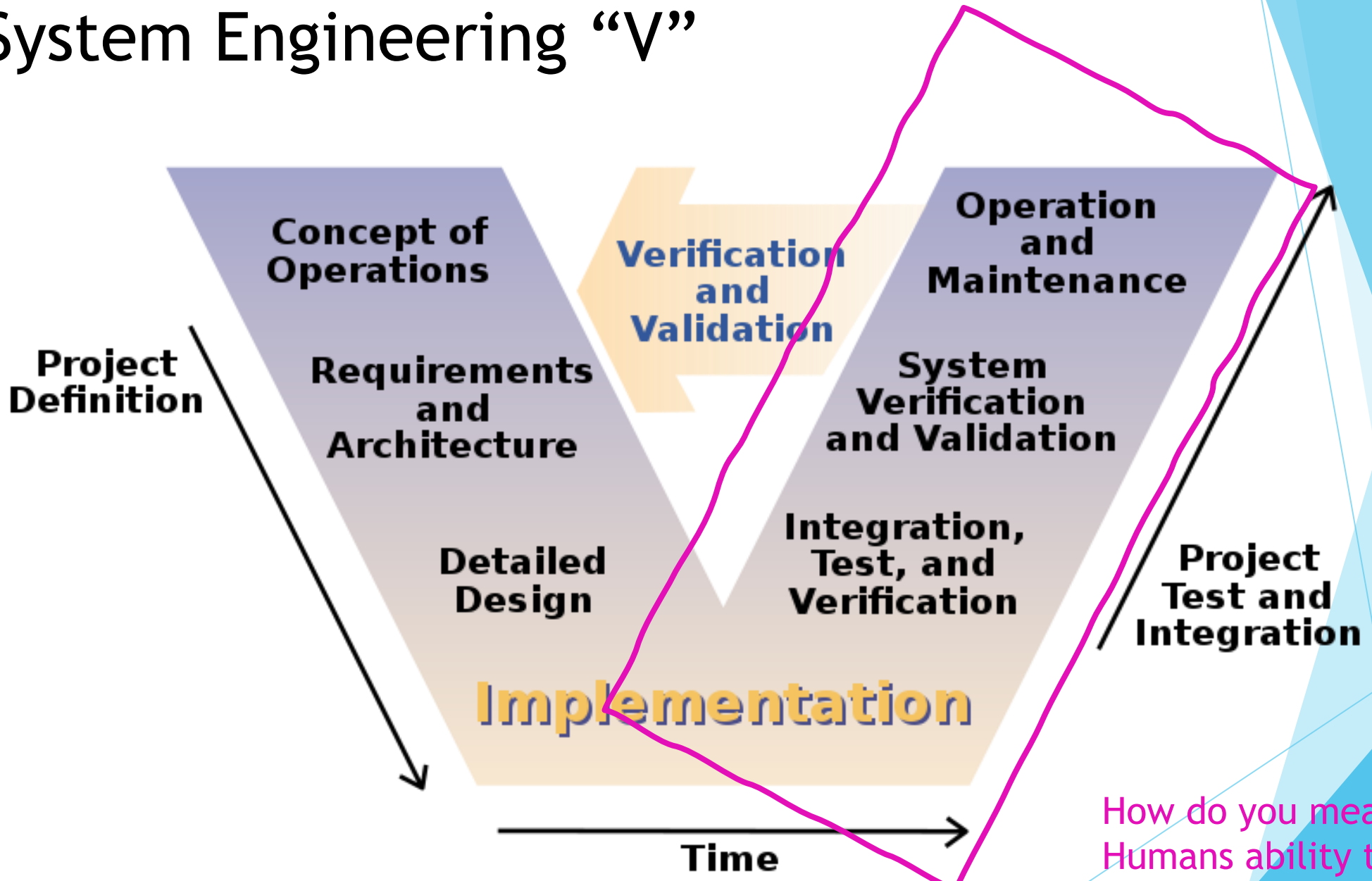
Human Factors Standards

Task Analysis: Understanding How Tasks Are Performed

- Analysis of how a task is accomplished, including a detailed description of both manual and mental activities, task and element durations, task frequency, task allocation, task complexity, environmental conditions, necessary clothing and equipment, and any other unique factors involved in or required for one or more people to perform a given task.

- Multiple types of Task Analyses that are used to answer specific questions or address specific design issues.
  - **Cognitive Task Analysis**
  - **Hierarchical Task Analysis**
  - **Goal Directed Cognitive Tasks Analysis**

System Engineering “V”



How do you measure the Humans ability to use the system properly?

Human Factors Tools to Support Verification and Validation

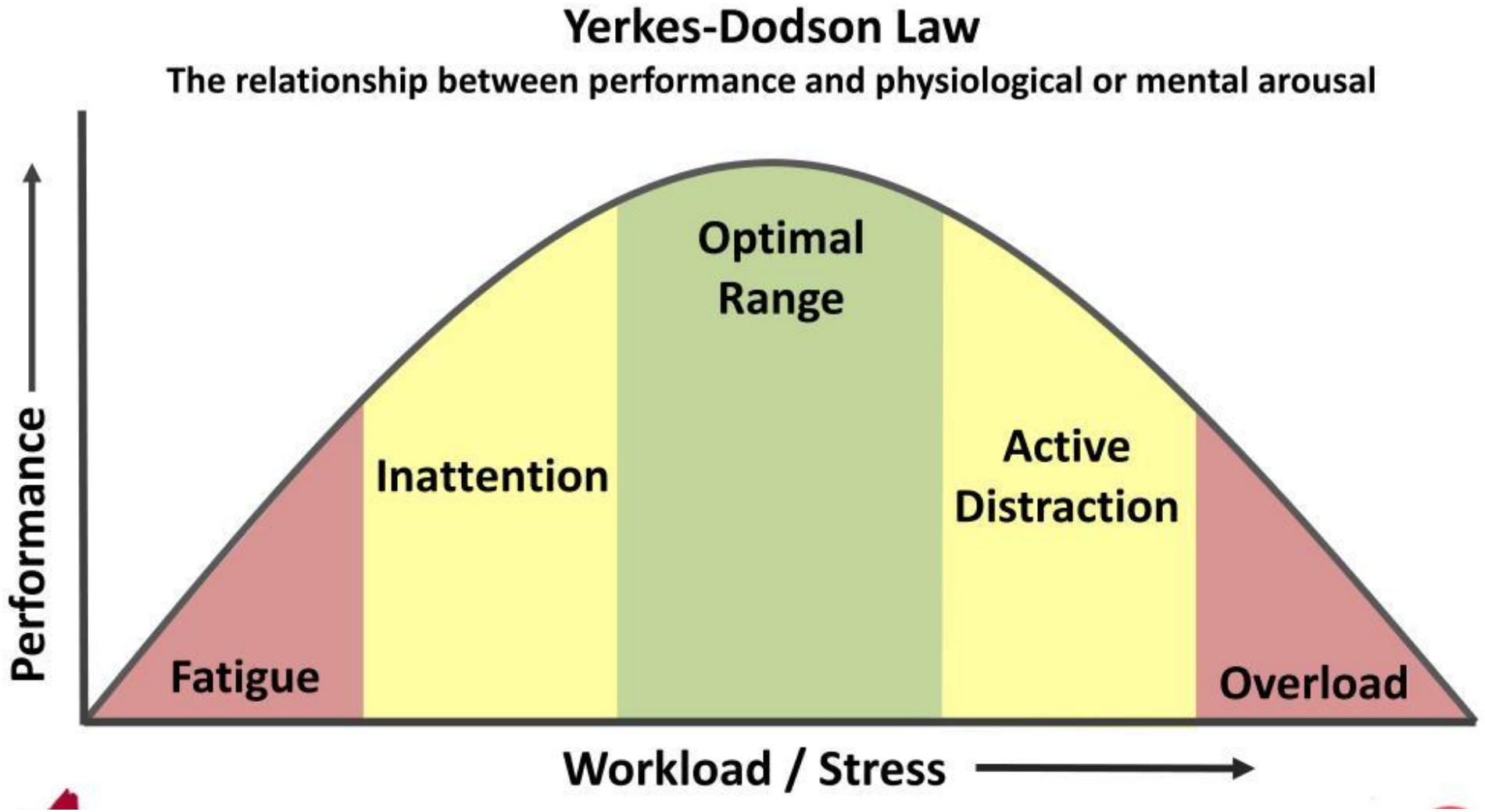
- Human Performance
  - Errors
  - Accuracy
  - Time
  - Adherence to procedures
- Reliability Assessments
- Usability Assessments
- Modelling
- Surveys, interviews, focus groups

- Workload
  - Subjective measures
  - Secondary Tasking
  - Physiological measures
- Situational Awareness
  - Objective measures
  - Subjective measures
- Physiological measures
  - Eye tracking
  - Brain Activity
  - Autonomic Systems

Mental Workload

- The level of mental resources required of a person at any one time.
- Can affect one's ability to process information, react to their surroundings, and to make decisions.
- Reducing these abilities increases the likelihood of an accident occurring.
  - Overload
  - Underload
- Degree of overload or underload depends on the mismatch between the demands of the task and the mental capacity that is available to meet those demands.

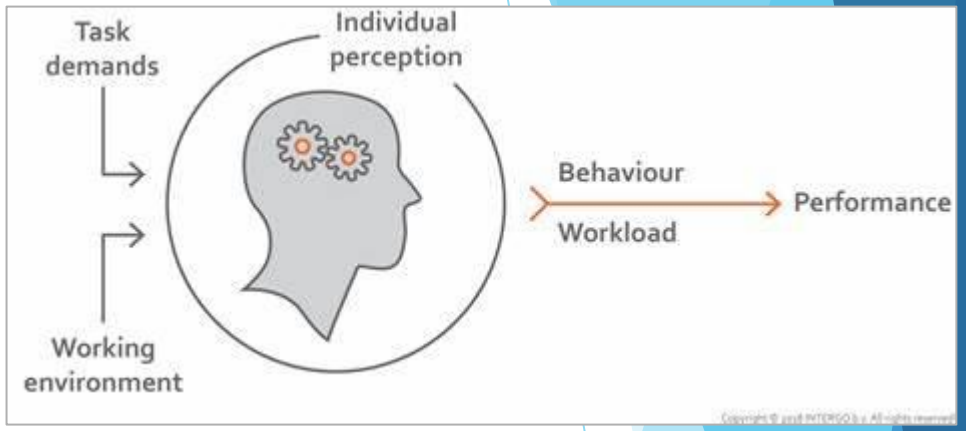
Fundamental Relationship between Workload & Performance



Source: https://image1.slideserve.com/1844832/fundamental-relationship-between-workload-performance-l.jpg

Measures of Mental Workload

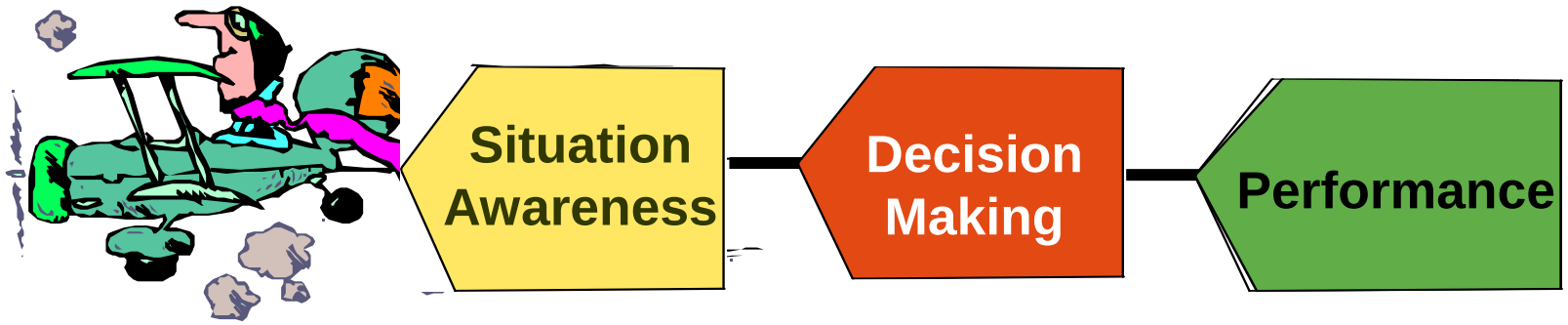
- How well was the task performed in terms of speed and/or accuracy?
  - Primary Task Performance Measures
  - Secondary Task Performance Measures
- How hard did the task(s) seem to the operator?
  - Subjective Measures
    - NASA-TLX
    - SWAT
- What physiological effects on operator were observed?
  - Heart rate variability
  - Mean heart rate
  - Pupil diameter
  - Hormonal chemistry (cortisol)



https://www.intergo.nl/en/

Scale
Mental Demand
Physical Demand
Temporal Demand
Effort
Performance
Frustation Level

Situation Awareness (SA)

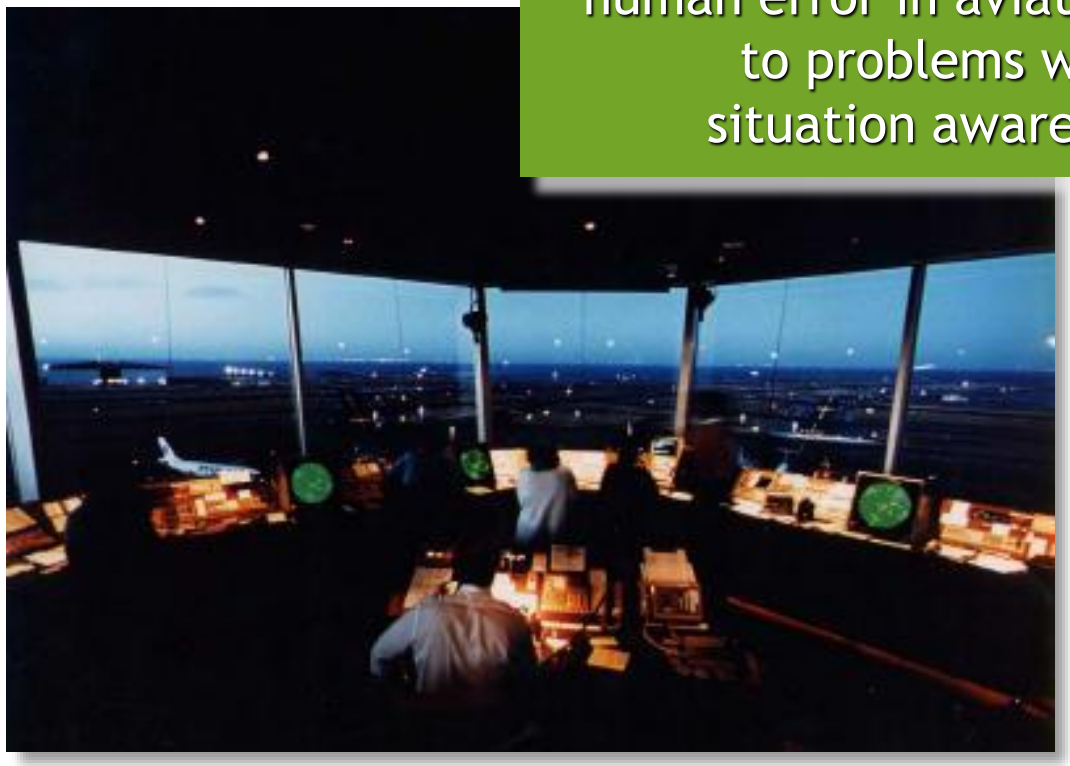


Situation Awareness Is Critical for Good Decision Making and Performance

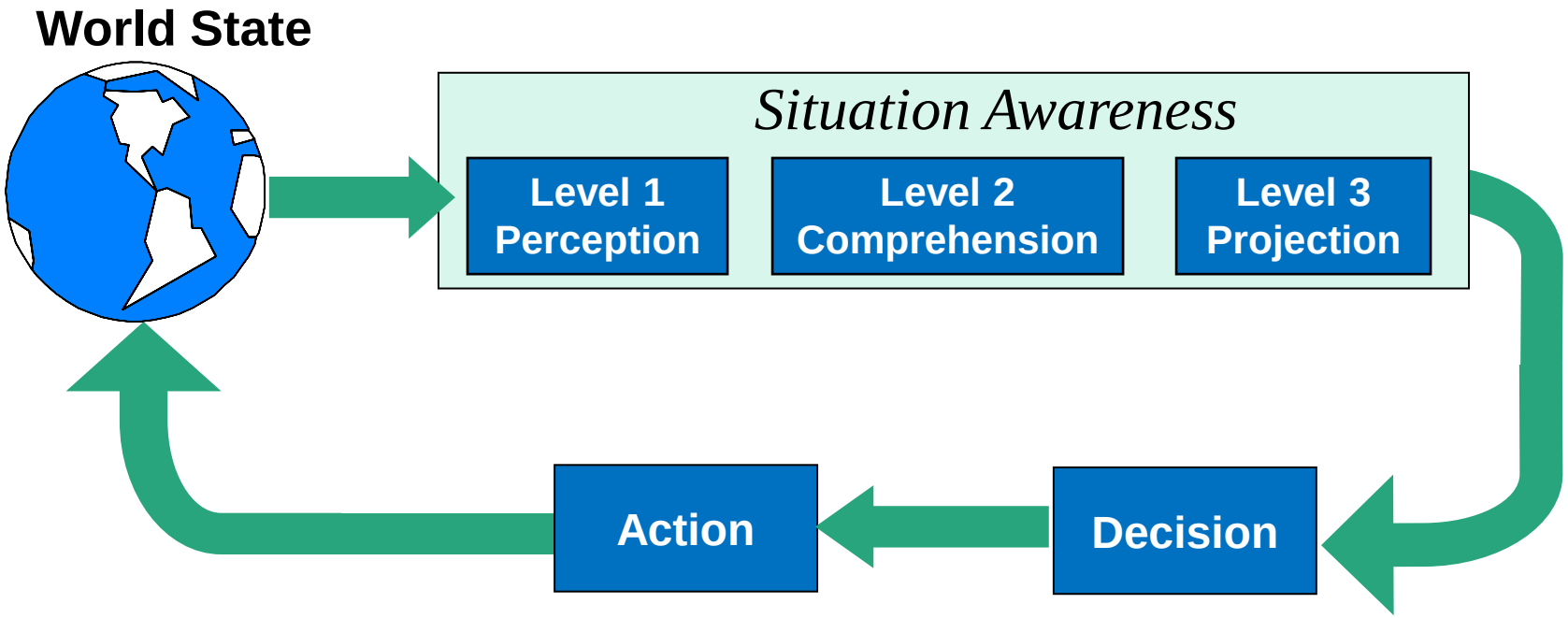
Must get the right information to the right person at the right time
in a form that is rapidly understandable and usable

Consequences of Poor SA

As much as 88% of human error in aviation is due to problems with situation awareness



SA Defined

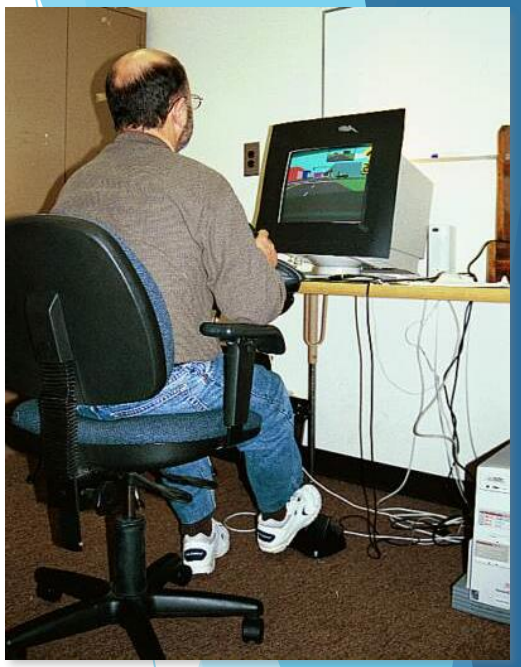


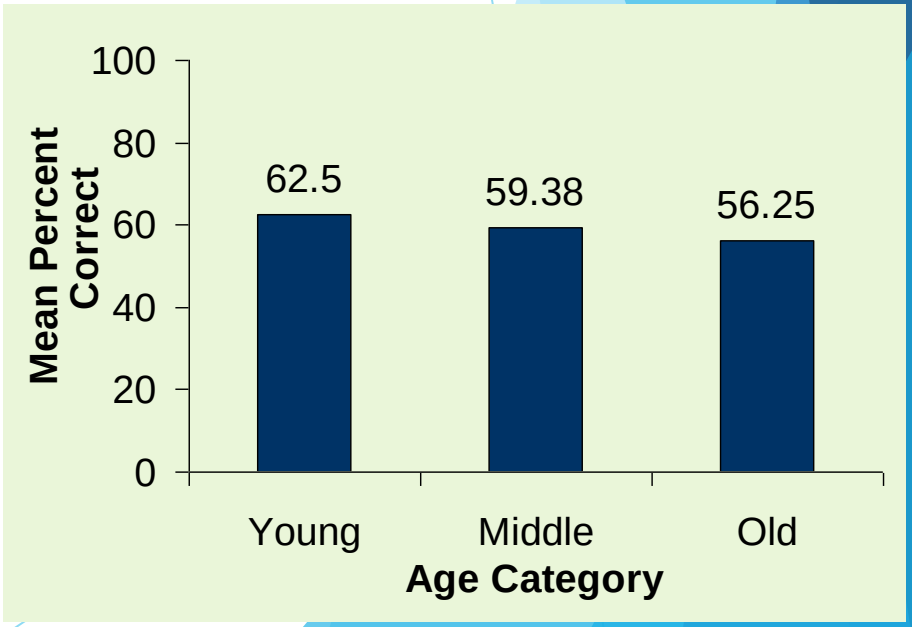
Situation Awareness is the Perception of the Elements in the Environment within a Volume of Time and Space, the Comprehension of their Meaning, and the Projection of their Status in the Near Future.

Endsley, 1988

Measures of SA

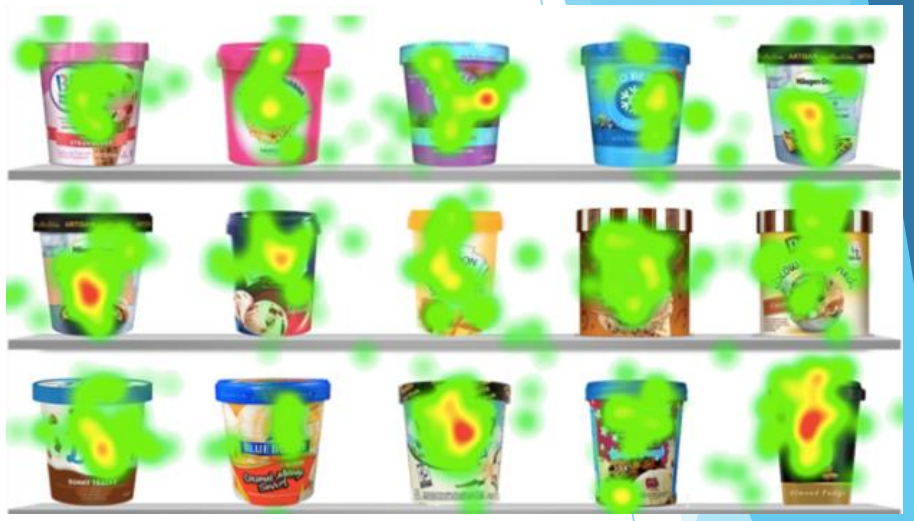
- Did the user focus on and attend to the critical pieces of information?
  - Process Indices
    - Eye Movements
    - Communications & Verbalizations
- Did the user interpret and comprehend the information appropriately?
  - Questionnaires
    - Post-test
    - On-line probes
    - SAGAT
  - Subjective Measures
- How well was the task performed?
  - Behaviors and Performance Measures
    - Actions
    - Verbalizations
    - Performance

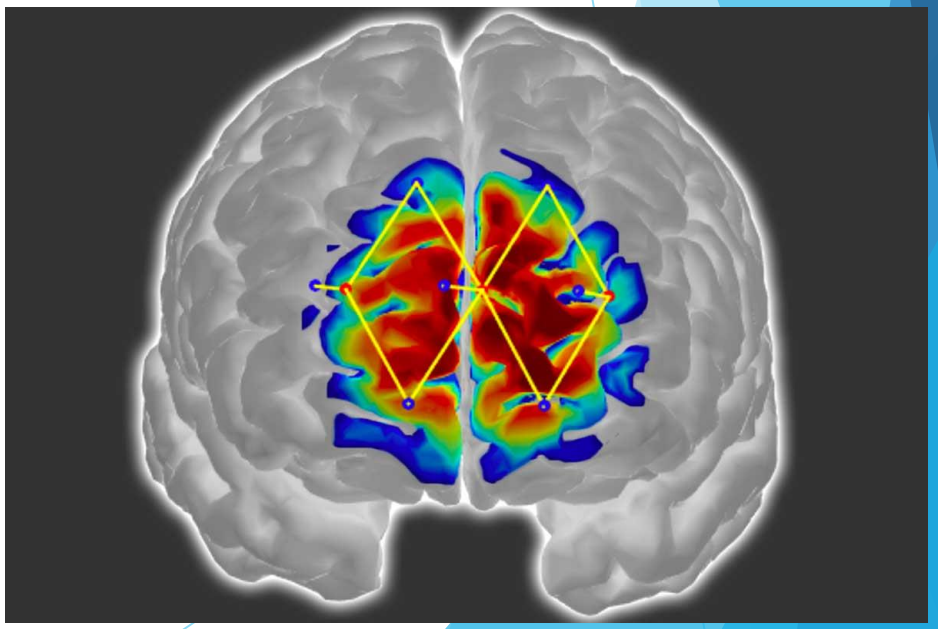




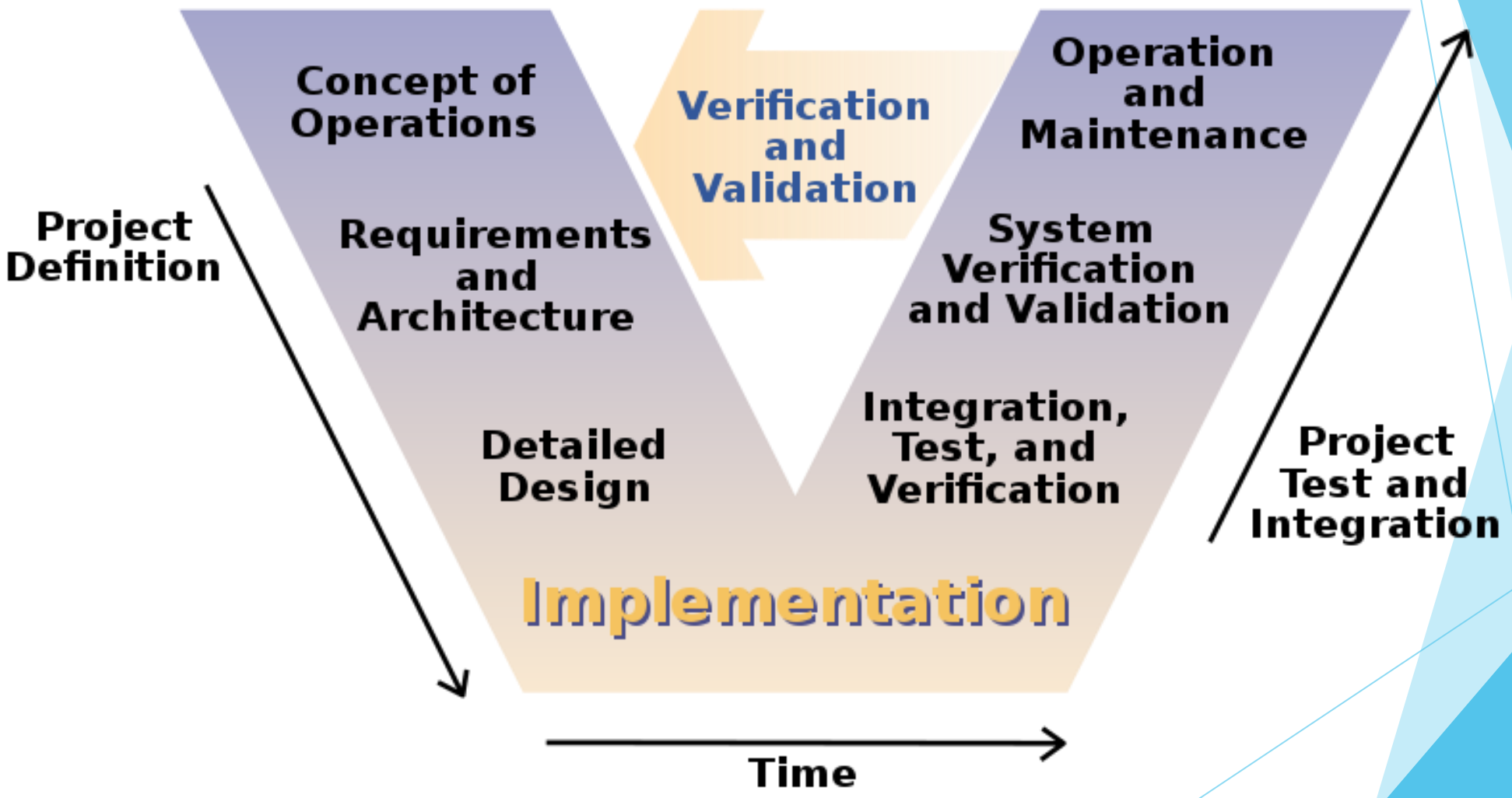
Physiological Measures

- Eye tracking
  - Measures Attention
    - Fixations (ex. heatmaps)
      - Fixation counts (how often looked at a location)
      - Fixation durations (how long looked at each location)
    - Saccades
    - Gaze paths (ex. gaze plots)
- Brain Activity (EEG, fMRI, CT)
  - Workload
  - Attention
- Autonomic Systems
  - Stress (Cortisol levels)
  - Skin resistance

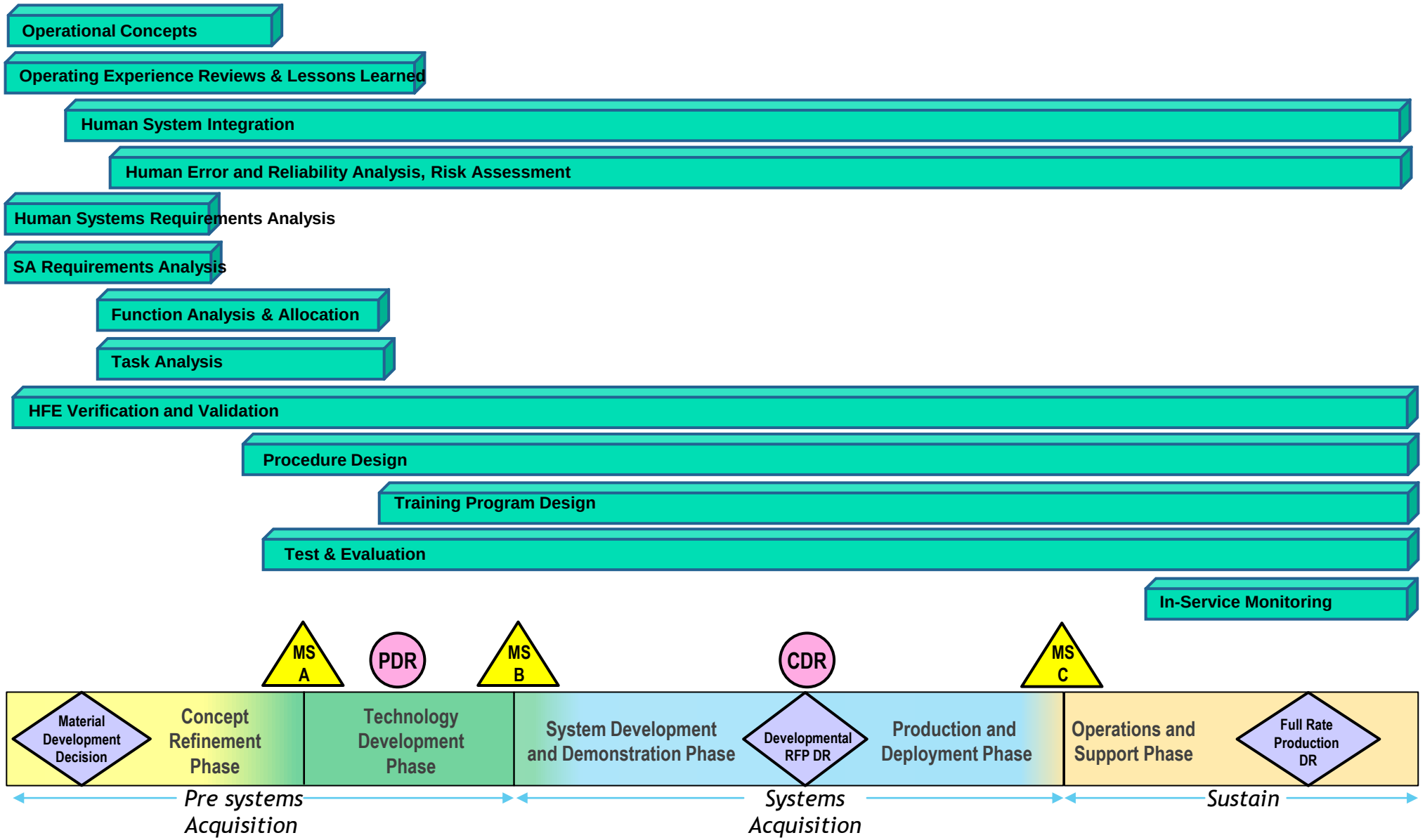




System Engineering “V”



HSI Integration Process/Principled Approach to Design



Human Systems Integration in SE

- Always remember there is a human involved somewhere in the loop

QUESTIONS?