

# Systems Engineering on California Highs-Speed Rail

## Lean Systems Engineering Working Group

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# CALIFORNIA HIGH-SPEED RAIL

## PROJECT BACKGROUND



- First High-Speed Rail in U.S.
- Construction has started
- SF to LA in under 3 hours by 2029
- 800 Miles, 24 stations
- Operating Speed of 220 mph



# Lean Management of Complex Programs

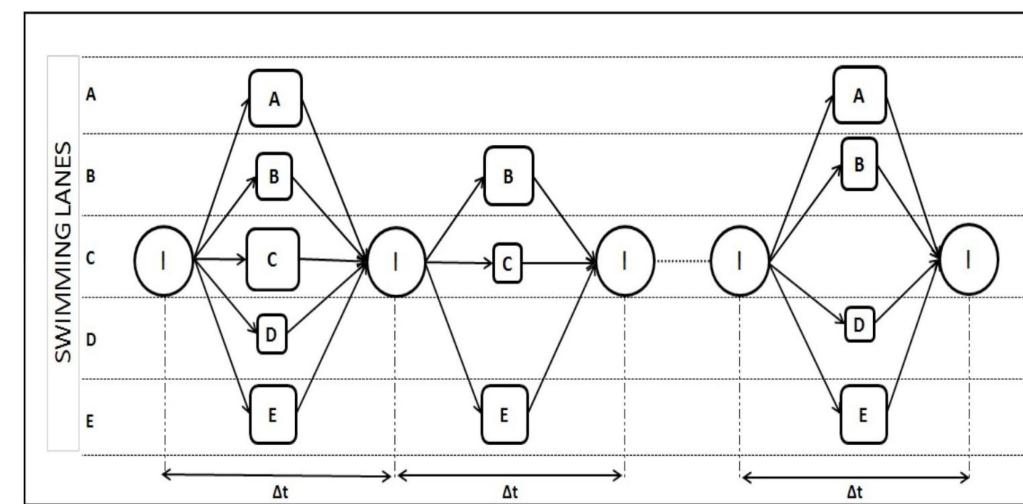
HSR Authority, São Paulo  
April 4, 2014

## Lean Product Development Flow (LPDF) Method for Projects

Is it possible to execute one-off projects as predictably and efficiently as a car assembly line?



worker  
secondary object (e.g. a satellite assembly)



The flow proceeds through the alternating work periods called Takt Periods (short and of equal duration) and Integrative Events “I”, providing common, frequent rhythm and flow to the entire project team.

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# Overcoming Engineering Silos by Applying Systems Engineering Principles

## Case Study: California High-Speed Rail System

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**Abstract.** Due to their size, large projects are often subdivided into a number of organizational and functional units to remain manageable. Examples include subsystem (e.g. operations, infrastructure, track, systems, rolling stock, procurement contract (e.g. guideways, tunnels, stations, facilities, systems, etc.) typically managed independently, reporting to an overall program/project manager of command. While this addresses the need for scope, cost and schedule management, it often at the cost of an inclusive, global engineering perspective. This frequently creates “engineering silo” solutions which, though perfectly designed and functional within their respective systems, may not necessarily be compatible with each other, as illustrated in Figure 1.

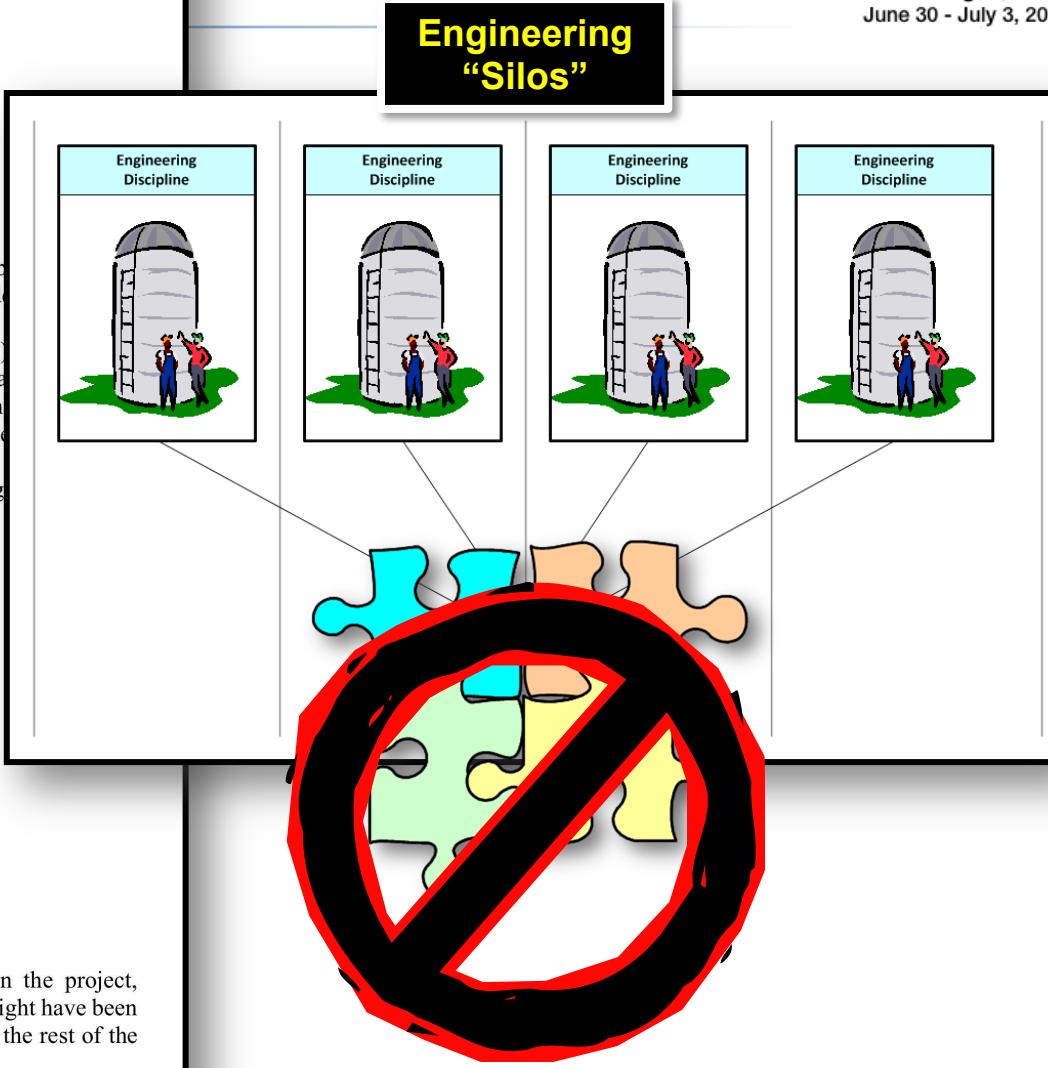


Figure 1: Building a Car with Engineering Silos [1]

The effects of independent engineering are often not identified until late in the project, typically during construction, system integration or start-up testing. Contracts might have been accepted before it is realized that the subsystems are not fully compatible with the rest of the system.

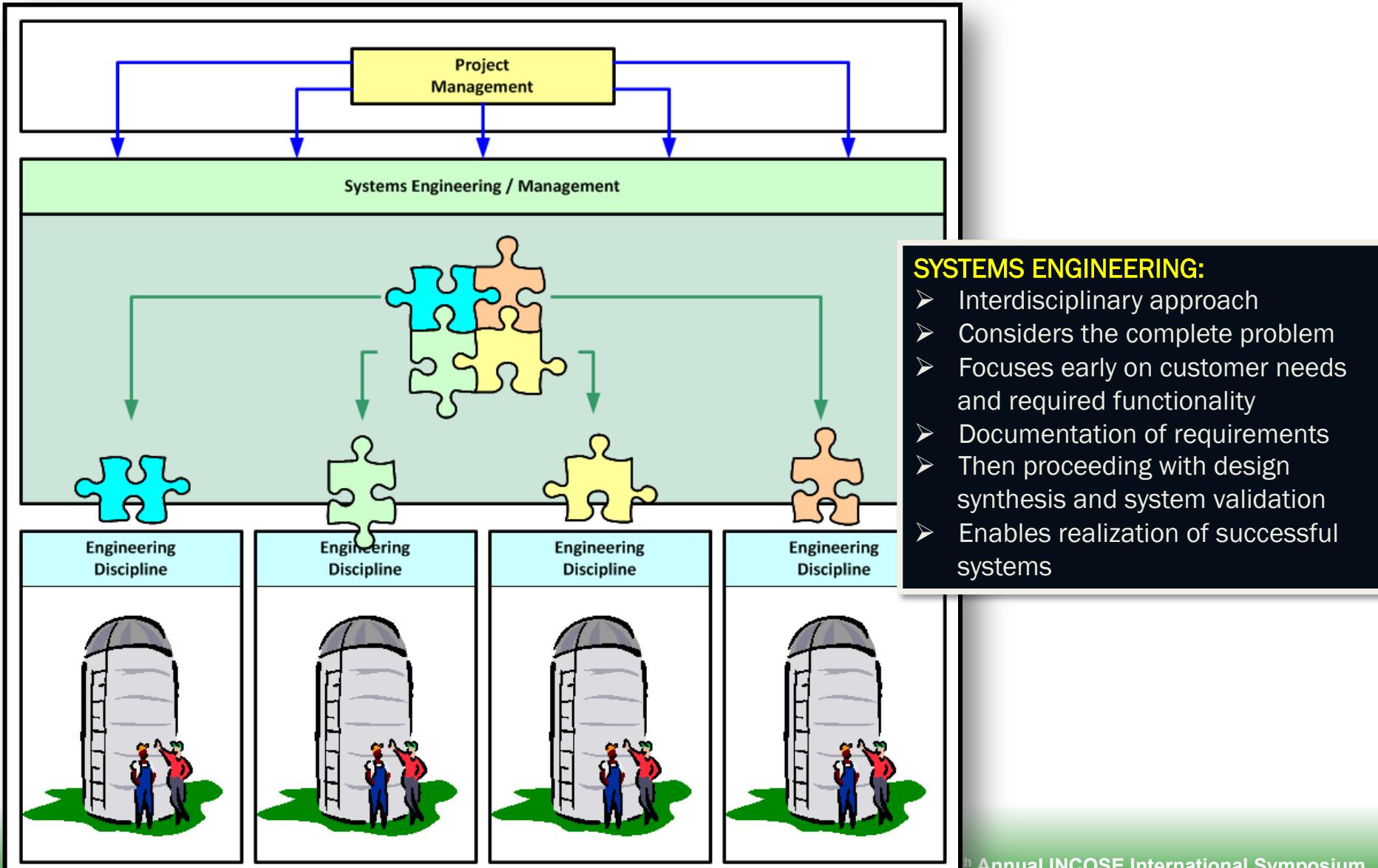
This paper describes how the California High-Speed Rail System (CHSRS) project uses Systems Engineering (SE) principles to overcome the engineering silo mentality, leading to a better product with fewer defects, unplanned rework and associated negative impacts on cost, schedule and reputation.

## Engineering “Silos”



# CALIFORNIA HIGH-SPEED RAIL

## EARLY INTEGRATION ACROSS DISCIPLINES



# CALIFORNIA HIGH-SPEED RAIL

## USER REQUIREMENTS ANALYSIS

### Scenario 4-9 – Hot Axle Bearing Detector

CHSRS rolling stock will have an on-board detector to monitor the health of the axle bearings. Among the functions of the detector is the ability to detect a hot bearing. The equipment will also be capable of interfacing with other axle bearing detectors (HABD).

The scenarios below are based on the following assumptions:

- All monitoring of CHSRS rolling stock will be done by the monitoring system.
- The intent of CHSRS wayside HABDs is to detect a hot bearing before it enters the CHSRS main track.
- Wayside HABDs will only be placed at the locations where foreign railroads enter onto, or pass through, the CHSRS main track.
- Wayside CHSRS HABDs will be interfaced with the monitoring system and the ATC system.
- Wayside HABDs of other railroads will not be interfaced with the monitoring system.

Alarm indications from wayside HABDs will be sent to the workstations used by Train Dispatchers (TD) and the Director of Operations Control (DOC).

- Director of Operations Control (DOC)
- Deputy Director of Operations Control (DDOC)
- Infrastructure Operations Controller (IOC)
- Security Operations Controller (SOC)

### Operational Scenario

#### Scenario 4-9A: HABD Detects Hot Bearing – Train Stopped Clear of Main Track

Why

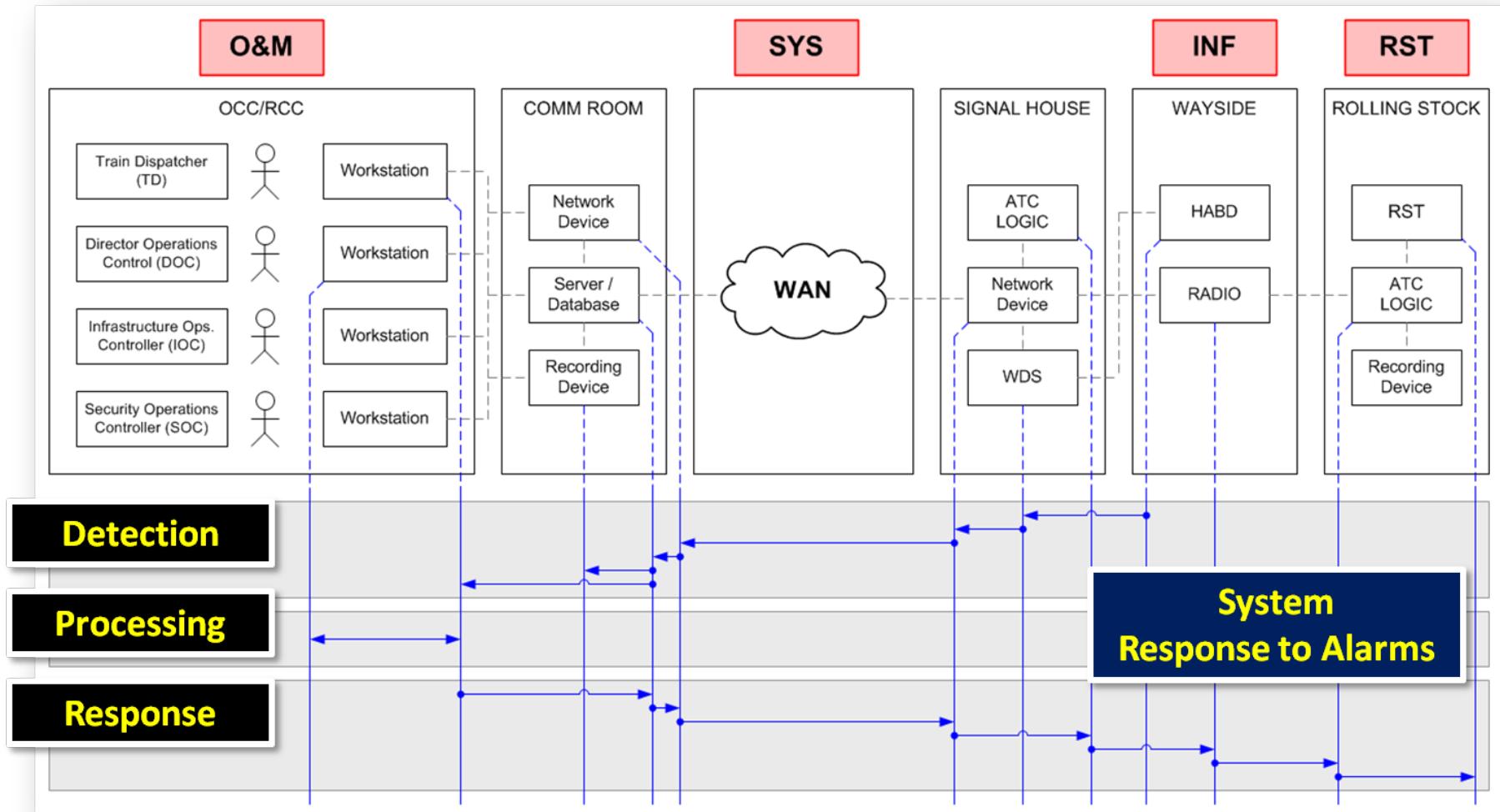
Foreign train approaching the CHSRS main tracks on a connecting track from another railroad passes HABD which detects a hot bearing. HABD sends input to Wayside Detector SCADA (WDS). WDS sends alert to default workstations.

User	Location	Systems	Role and Responsibilities
<b>HABD Detects</b>	<b>Hot Axle Bearing on Passing Train</b>		
Train Dispatcher	OCC/RCC	HABD WDS ATS ATC Telephone	<p><b>When</b></p> <ul style="list-style-type: none"> <li>• Train Dispatcher receives visual and audible alert on workstation indicating the location where a HABD has detected a fault.</li> <li>• Train Dispatcher confirms train movement through location.</li> <li>• Train Dispatcher uses Automatic Train Supervision – Manual (ATS-Manual) train control component of ATC system to issue stop command to foreign train.</li> <li>• Contact DOC via direct telephone line, relay pertinent information and action taken.</li> </ul> <p><b>Who</b></p> <p><b>Where</b></p> <p><b>How</b></p>
DOC	OCC/RCC	Telephone Radio	<ul style="list-style-type: none"> <li>• Confer with Train Dispatcher via direct telephone line; confirm pertinent information and action taken.</li> <li>• Contact foreign train via radio, relay reason for stop and instruction to check train for hot axle bearing. (Specific information provided to the extent HABD is capable of providing.)</li> <li>• Instruct crew they have a block on adjacent tracks (if any) to inspect train.</li> <li>• Instruct IOC and SOC via direct telephone line to check SCADA systems for indications of trouble.</li> </ul>
IOC	OCC/RCC	Engineering SCADA	<ul style="list-style-type: none"> <li>• Check engineering SCADA systems for indications of failures.</li> </ul>
SOC	OCC/RCC	Intrusion Detection System	<ul style="list-style-type: none"> <li>• Check intrusion detection (ID) SCADA system for anomalies.</li> </ul>
Locomotive Engineer	Train	Radio	<ul style="list-style-type: none"> <li>• Communicate via radio with DOC. Acknowledge instructions to inspect train and notify crew. Monitor radio for further instructions.</li> </ul>
Conductor	Train	Radio	<ul style="list-style-type: none"> <li>• Communicate with engineer via hand-held radio. Prepare to inspect train.</li> </ul>



# CALIFORNIA HIGH-SPEED RAIL

## HIGH-LEVEL SYSTEM ANALYSIS



# CALIFORNIA HIGH-SPEED RAIL

## MORE AT THE INCOSE IW15



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### Event Calendar

To submit an event, please send an e-mail to the [Communications Committee](#)

<a href="#">INCOSE IW 2015</a>	Jan 24 - 27, 2015
<a href="#">CSU/UM Asia 2014</a>	Dec 10 - 12, 2014
<a href="#">INCOSE UK Conference 2014</a>	Nov 18 - 19, 2014
<a href="#">5th International Conference on Complex Systems Design and Management</a>	Nov 12 - 14, 2014
<a href="#">Complex Adaptive Systems Conference</a>	Nov 03 - 05, 2014
<a href="#">EMEASEC 2014: Systems Engineering: Exploring New Horizons</a>	Oct 27 - 30, 2014
<a href="#">SEHR 2014 Annual Conference: Taking the Next Step: Systems Thinking in Action</a>	Oct 22 - 23, 2014
<a href="#">8th Annual INCOSE Great Lakes Regional Conference</a>	Oct 10 - 11, 2014
<a href="#">APOSEC 2014</a>	Oct 07 - 09, 2014
<a href="#">23rd International Conference on Systems Engineering (ICSEng 2014)</a>	Aug 19 - 21, 2014
<a href="#">INCOSE / IEEE EnergyTech 2014 &amp; AIAA Propulsion and Energy Forum and Expo</a>	Jul 28 - 30, 2014
<a href="#">24th International Symposium - INCOSE IS 2014</a>	Jun 30 - Jul 03, 2014
<a href="#">INCOSE NSWG Community of Practice Webinar</a>	Jun 19, 2014
<a href="#">Webinar 15:00 UTC: "An ITIL Approach to System Engineering"</a>	Jun 18, 2014
<a href="#">KSEE: Kongsberg Systems Engineering Event</a>	Jun 12 - 13, 2014
<a href="#">2014 9th International Conference on System of Systems Engineering (SOSE 2014)</a>	Jun 09 - 13, 2014
<a href="#">9th International System of Systems Engineering Conference</a>	Jun 09 - 13, 2014
<a href="#">CESUN 2014</a>	Jun 08 - 11, 2014
<a href="#">Nordic Systems Engineering Tour</a>	May 20 - 24, 2014
<a href="#">INCOSE NSWG Community of Practice Webinar</a>	May 16, 2014
<a href="#">Invitation to 2nd International Spring School on Systems Engineering (IS3E)</a>	May 12 - 16, 2014

Done



24<sup>th</sup> Annual INCOSE International Symposium

# CALIFORNIA HIGH-SPEED RAIL

VISIT US ON TUESDAY JULY 1, 2014

When, Where	What	Who (or Description)
8-9:30am <a href="#">Check location</a> during registration	<b>Keynote speaker</b> <i>Thinking differently about systems engineering change programs – dogs, bears and magic numbers</i>	Scott McArthur, Sculpture Consulting Ltd
10:00-12:10pm  Track 4 La Sirena IV	<b>Paper Session</b> <i>Perspectives on SE</i>	<b>Session chair:</b> Nita Rabadia (HS2)
	<i>On Motivating People to Implement Systems Engineering Getting from the Necessary to the Impossible</i>	Oliver M. Hoehne (Parsons Brinckerhoff, Transit & Rail Systems)
	<i>What color is your nail polish? How to use Myers-Briggs personality characteristics to identify potential Systems Engineers in your organization</i>	Jennifer L. Russell (Parsons Brinckerhoff)
	<i>Coming in Under Par: What Golf Can Teach Us About Systems Engineering</i>	David D. Walden (Sysnovation, LLC)

**Transportation WG Presentations,  
Recommended by  
Energy & Infrastructure WGs**



# What color is your nail polish?

## How to use Myers-Briggs personality characteristics to identify potential Systems Engineers in your organization

Jennifer L. Russell, EISE  
Lead Systems Engineer  
Parsons Brinckerhoff

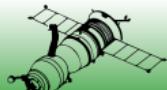


# Nail Polish?

- IS13 ~ 30% women; most wore blue/green toe nail polish



Do these  
Systems  
Engineers  
have  
something in  
common?



# Capturing the essence of SE

- Competency model
- Kasser, Hitchins, Frank, Zhao (2012)
  - Personal skills assessments and competency models found consistency
  - Systems Engineers
    - Learn new skills
    - Have mental flexibility
    - Hone their competencies



- Definition of competency varies
- Skills vary by industry, position, and function

### 3. ROLES AND ACTIVITIES OF SYSTEMS ENGINEERS

- The role of the systems engineer in the workplace depends on the situation.
- Definitions and descriptions of systems engineering currently comprise different interpretations of the broad raft of activities that systems engineers might undertake according to their role in the workplace.



# Capturing the essence of an SE

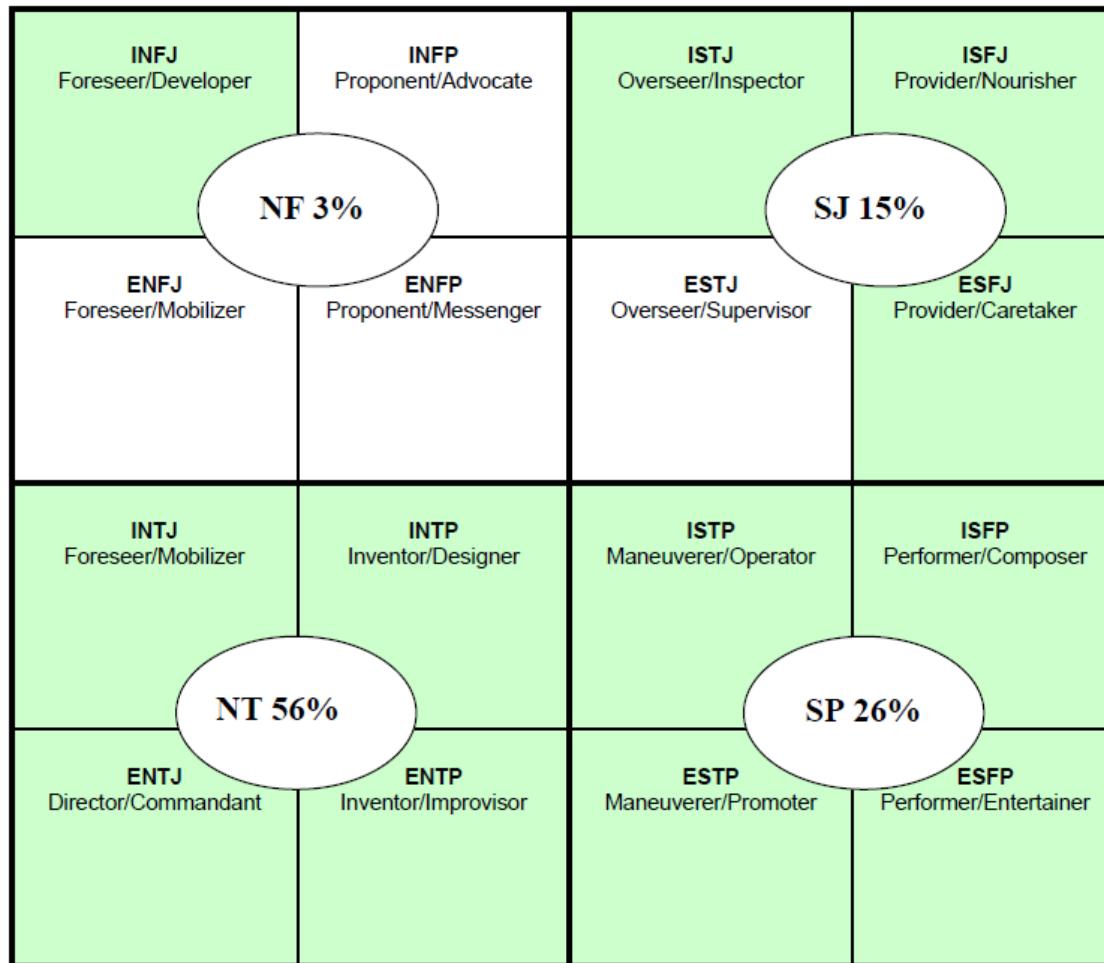
- Williams and Derro (2008) NASA
  - Seeking predictors of success
  - Identified observable behaviors

**Table 1 Behavioral Competency Model Framework**

Level	Description	Example
Top: Themes	Collections of competencies	Attitudes and Attributes
Middle: Competencies	Aggregations of related observable behaviors	Seeks information and uses the art of questioning
Lowest: Actual Behaviors	Observable behaviors	Asks difficult questions of discipline or subsystem experts regarding boundaries, conditions, and assumptions to ensure continuity across all systems, and to ensure the proposed solution is an integrated solution and fundamentally makes sense

# Williams and Derro (2008)

Figure 3 MBTI® Types Occurring in SEs Studied Across the Agency



SE MBTI types represented  
across the Agency



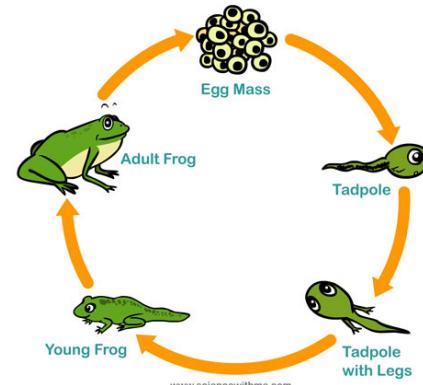
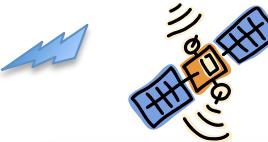
# Why look for Systems Engineers

- Part of INCOSE mission “To share, promote, and advance the best of systems engineering...”
- Growing into emerging domains
  - Biomedical
  - Infrastructure
  - Power & Energy
  - Transportation



# Challenges in emerging domains

- Unreasonable to test for SE competency
- Teams don't know Systems Engineering
- Confusion of terms
  - System
  - Architecture
  - Life-cycle



# How emerging domains grow

A. Grassroots approach

B. Leader-driven

- Fragile “test case”
  - Needs to be logical, be right, and be accepted



Alstom MF2000 for Paris Metro



# Cognitive Psych

Comprehension skills

Competency skills

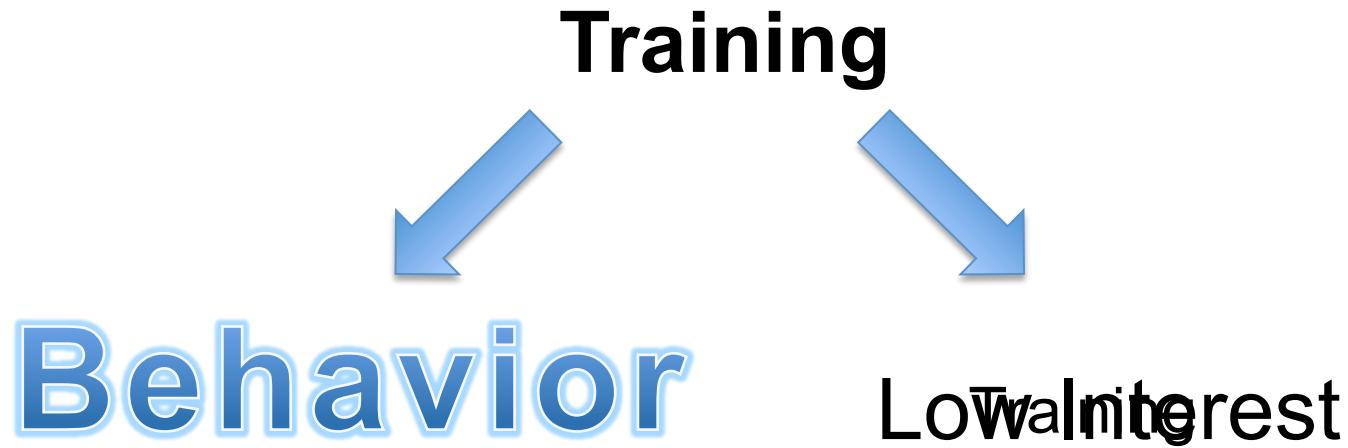
Flexibility

- National Research Council (2000) consolidated previous decades of research on how we learn
  - Comprehension
  - Effective application of knowledge
  - Competency

... all increased when learners had an **INTEREST** in the subject

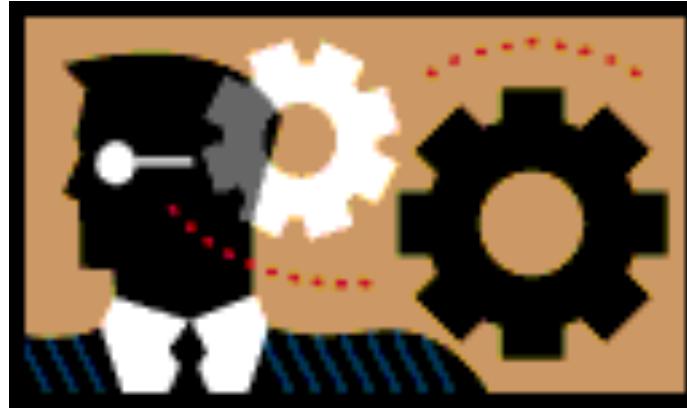


# Getting closer to success

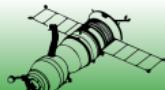


# Interested?

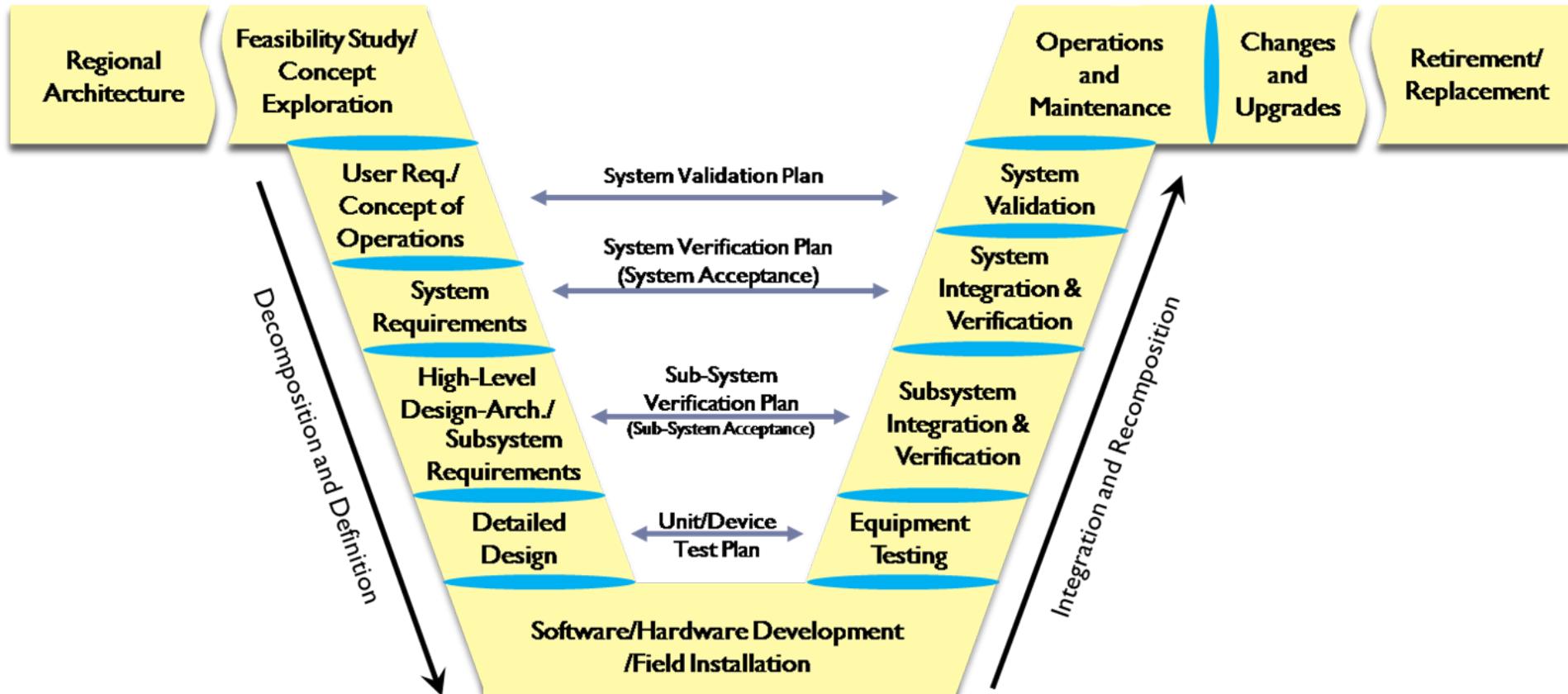
- Sometimes visible, identifiable actions
- Phenomenon ~ people do what they like to do



- Therefore, best to find people who may be naturally inclined toward SE behaviors



# Step 1: Understand your tasks

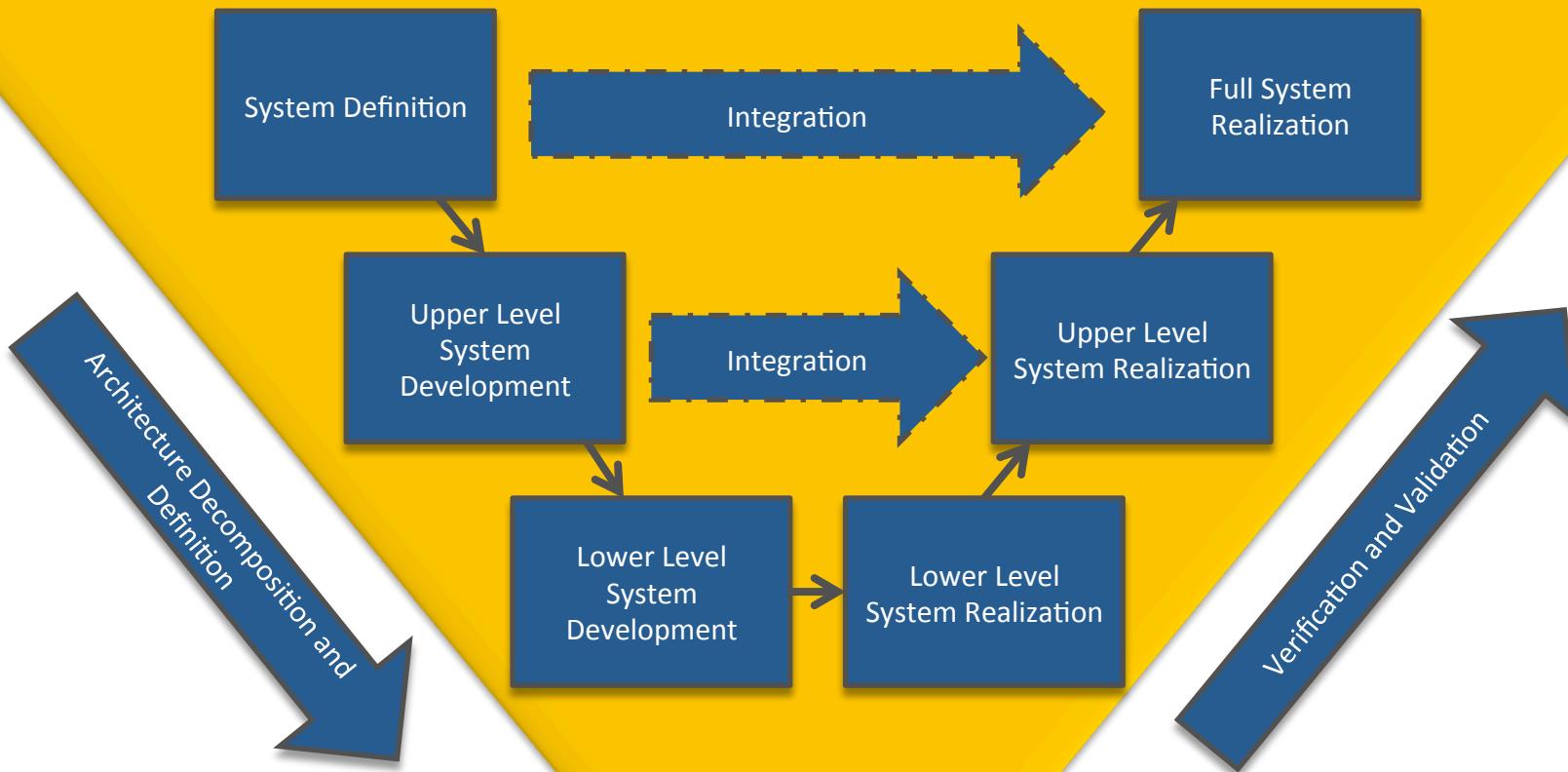


Timeline

Design Gate



# Step 1: Understand your tasks



# Map tasks to characteristics

- System Definition
- Architectural Decomposition
- Integration
- Verification and Validation



# System Definition

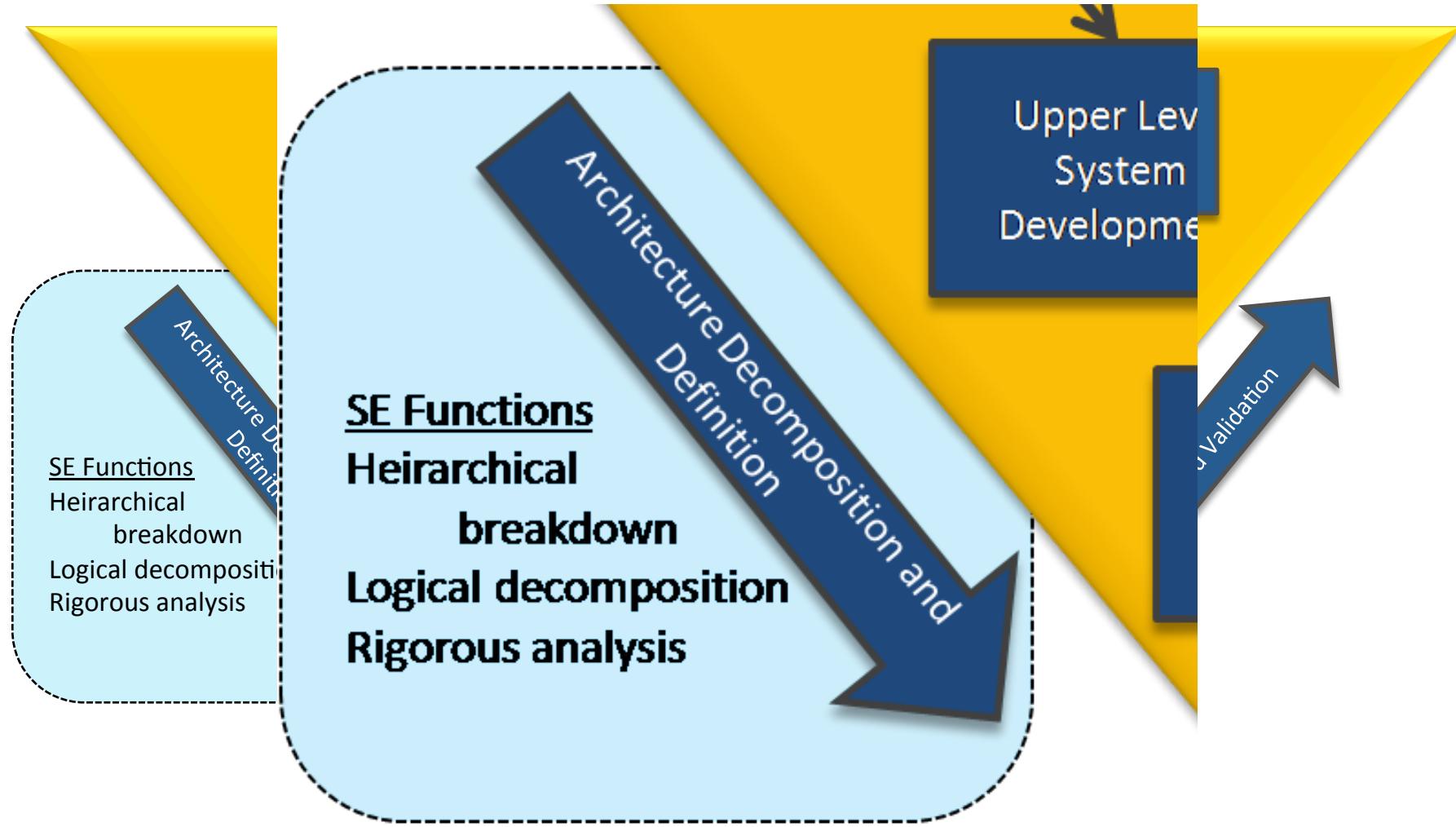
SF Functions

**SE Functions**  
**Connecting**  
**Understanding**  
**Synthesizing**

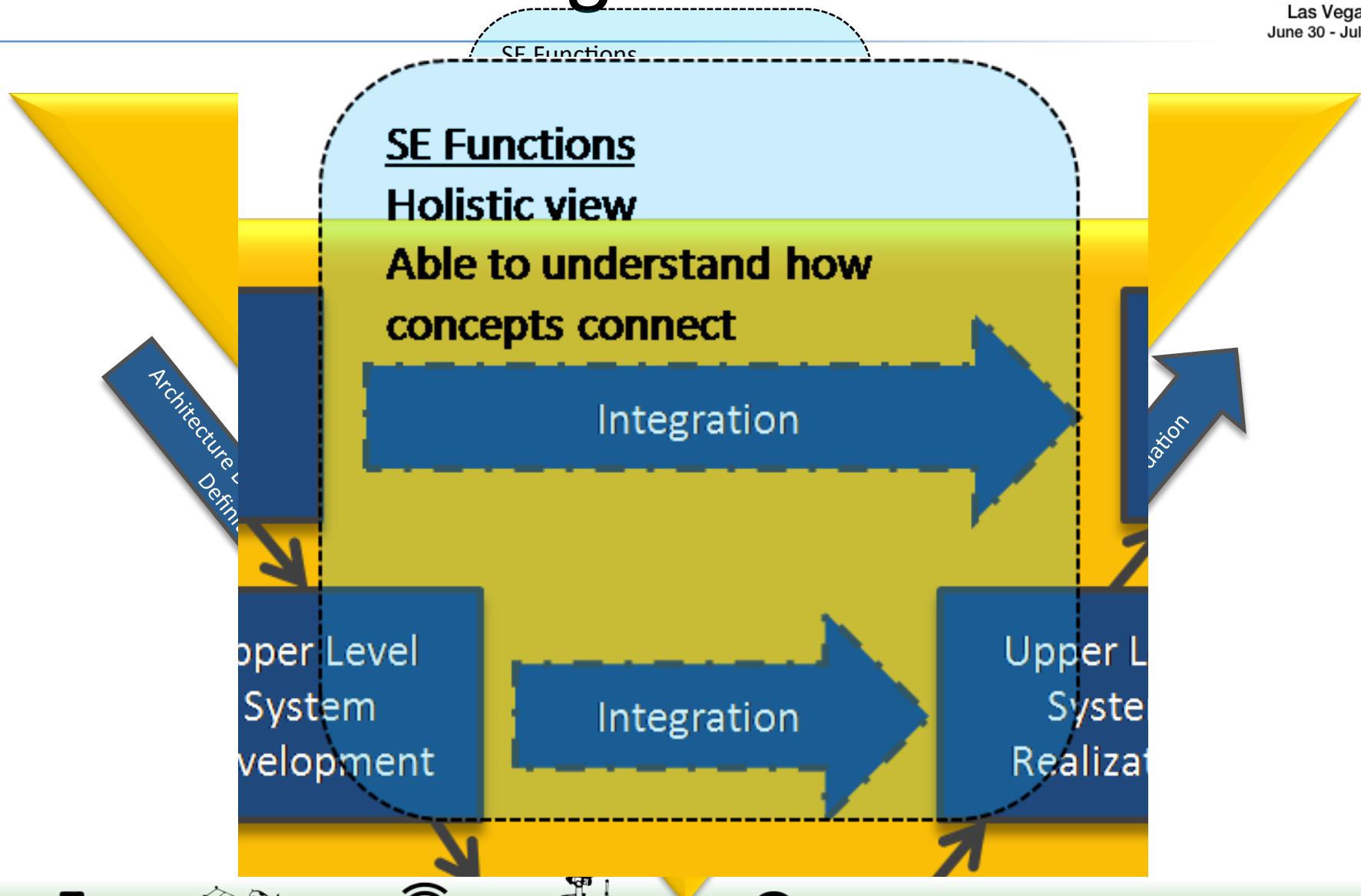
System  
Definition



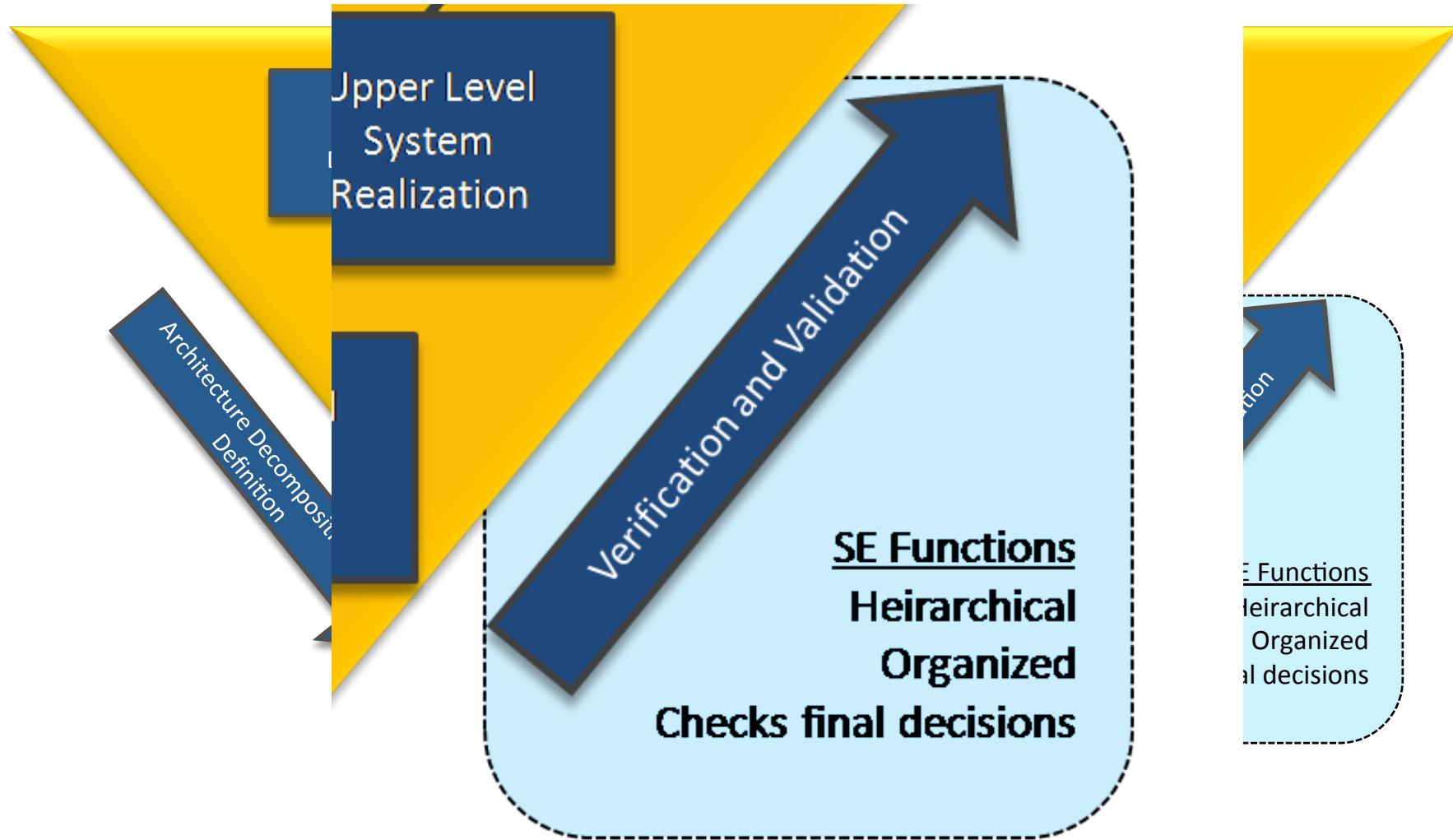
# Architectural Decomposition



# Integration



# Verification and Validation



# Step 2: Select Assessment

- Myers Briggs Type Indicator (MBTI)
- DiSC
- Keirsey Temperament Sorter
- True Colors
- Insight Inventory
- ...



# Step 3: Understand the assessment

- MBTI
  - Developed in early 1940s
  - Based on Jungian theories – psychological attitude and functions
    - Describes preferences
    - Not prediction of behavior
  - Purpose: identify strengths in lieu of experience



# Getting closer to success



# Step 4: Apply Characteristics

- Energy
  - Introversion
  - Extroversion
- Decisions
  - Thinking
  - Feeling
- Information
  - Sensing
  - Intuitive
- Structure
  - Judging
  - Perceiving



# Structure - Judging

- Heirarchical
- Organized
- Prefers fixed (non-flexible) structure





# External Structure

## Judging

Heirarchical

Organized

Prefers fixed (non-flexible)  
structure

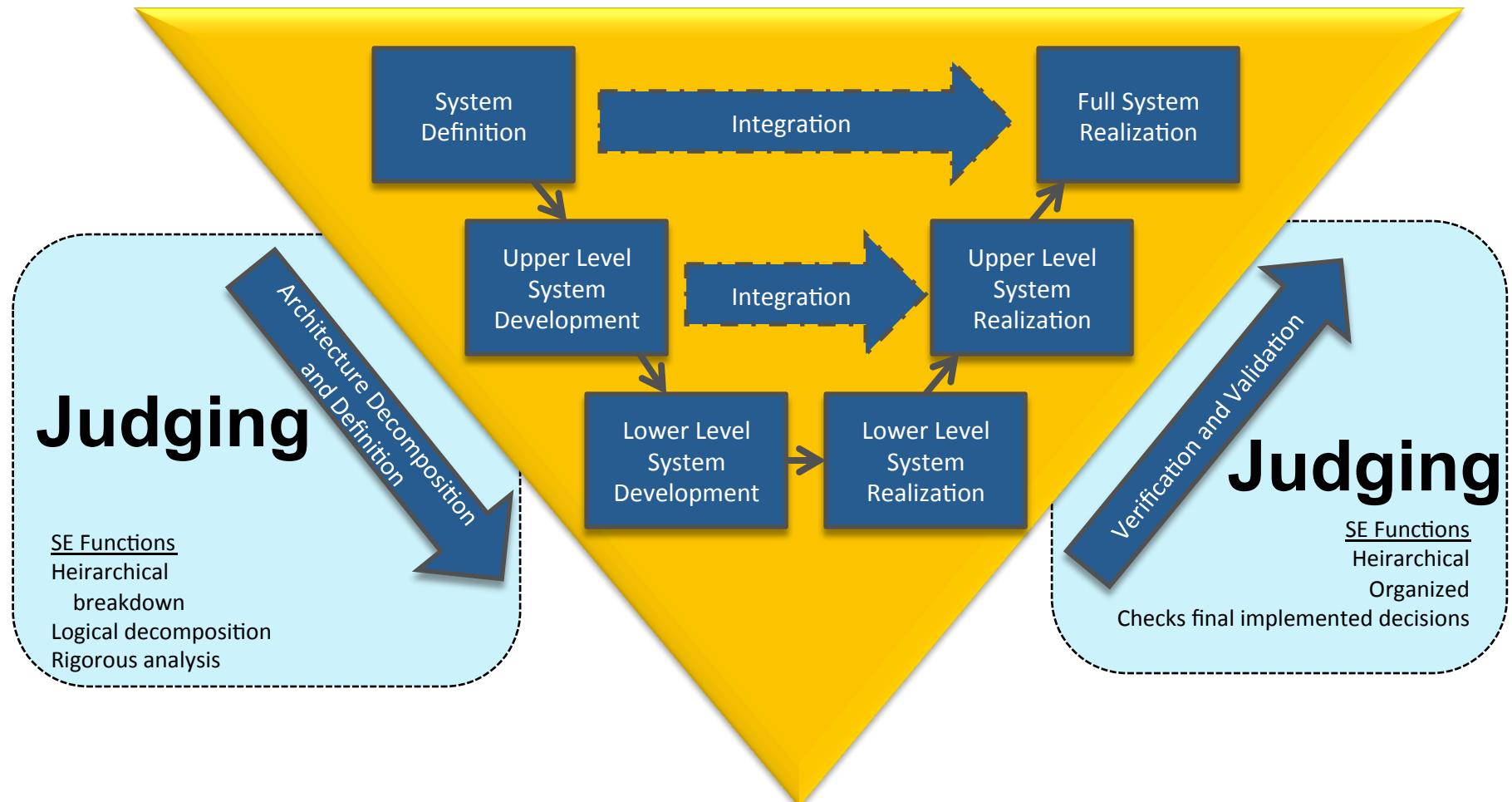
## Perceiving

Flexible

Open Ended

Prefers adjustable structure





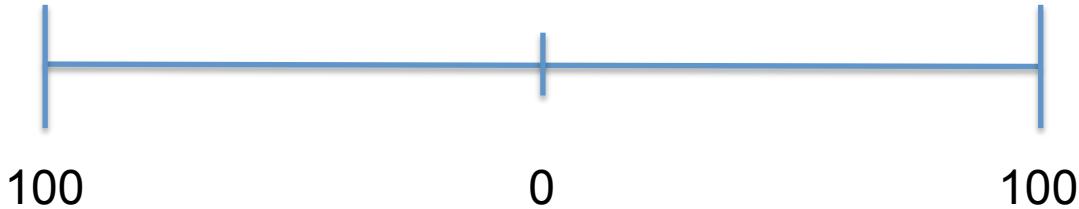
# Information – Sensing

- Discrete, independent parts make a whole
- Step-by-step is best
- Logical and analytical
- Looks for details





# Information Processing



## Sensing

Discrete, independent parts  
make a whole

Step-by-step is best

Logical and analytical

Looks for details

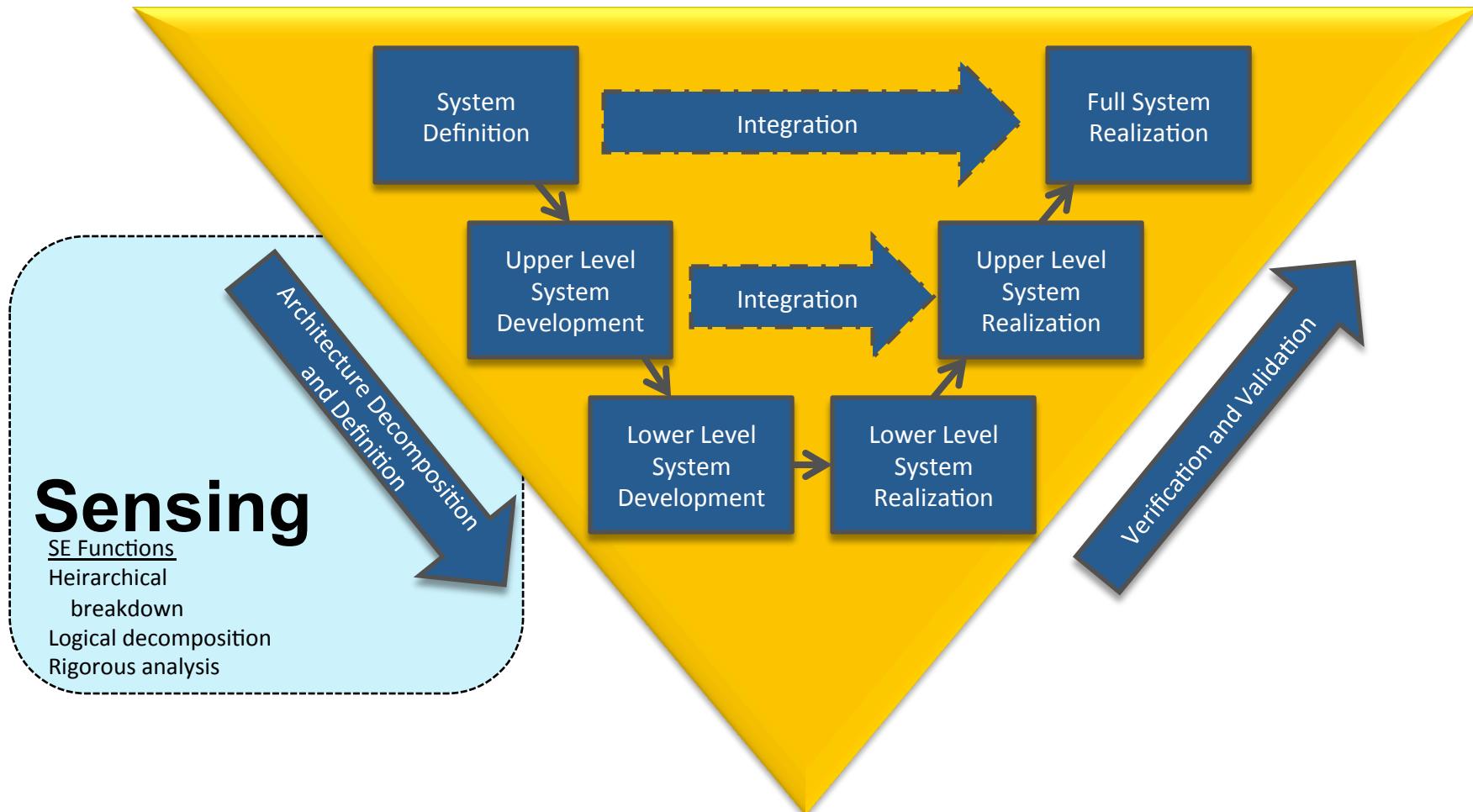
## Intuitive

Holistic view of parts making  
a whole

Applies new concepts with  
little direction

Needs to see the whole  
picture





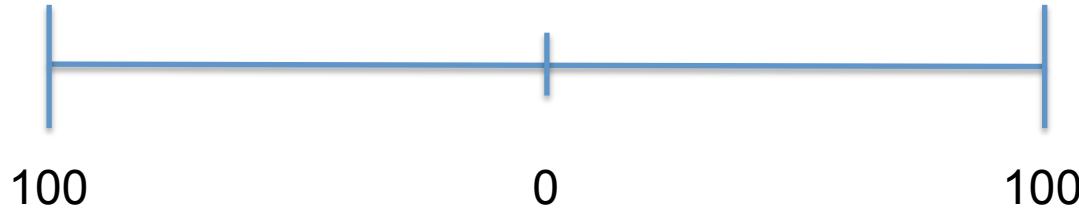
# Structure – Perceiving

- Flexible
- Open Ended
- Prefers adjustable structure





# External Structure



## Judging

Heirarchical

Organized

Prefers fixed (non-flexible)  
structure

## Perceiving

Flexible

Open Ended

Prefers adjustable structure



# Perceiving

SE Functions  
Connecting  
Understanding  
Synthesizing

System  
Definition

Integration

Full System  
Realization

Upper Level  
System  
Development

Integration

Upper Level  
System  
Realization

Architecture Decomposition  
and Definition

Lower Level  
System  
Development

Lower Level  
System  
Realization

Verification and Validation



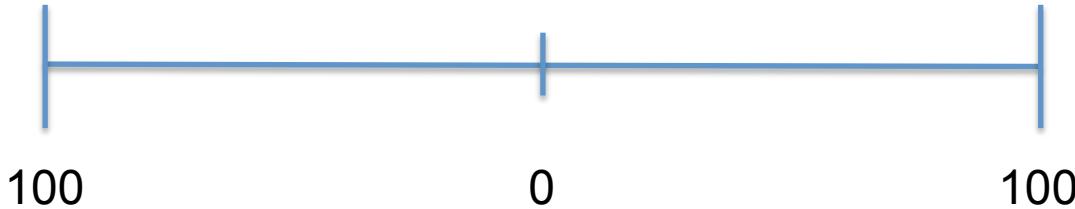
# Information – Intuitive

- Holistic view of parts making a whole
- Applies new concepts with little direction
- Needs to see the whole picture





# Information Processing



## Sensing

Discrete, independent parts  
make a whole

Step-by-step is best

Logical and analytical

Looks for details

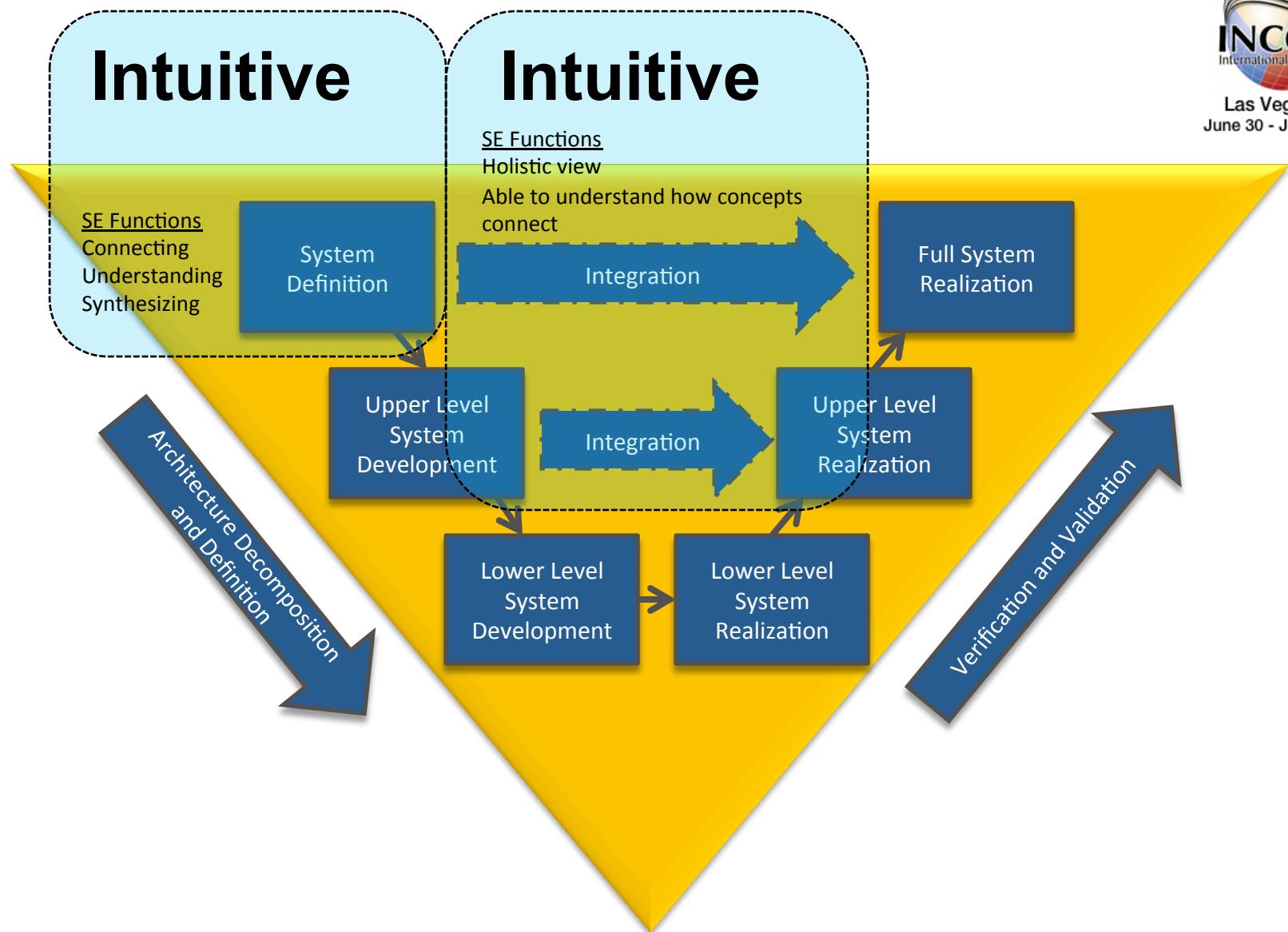
## Intuitive

Holistic view of parts making  
a whole

Applies new concepts with  
little direction

Needs to see the whole  
picture





# Apply Characteristics to Tasks

## Intuitive Perceiving

SE Functions  
 Connecting  
 Understanding  
 Synthesizing

System  
Definition

## Intuitive

SE Functions  
 Holistic view  
 Able to understand how concepts connect

Integration

Full System  
Realization

## Judging Sensing

SE Functions  
 Heirarchical  
 breakdown  
 Logical decomposition  
 Rigorous analysis

Architecture Decomposition  
and Definition

Upper Level  
System  
Development

Integration

Upper Level  
System  
Realization

Lower Level  
System  
Development

Lower Level  
System  
Realization

## Judging

SE Functions  
 Heirarchical  
 Organized  
 Checks final implemented decisions



# Don't do this...



# Questions?



# WHO

# Be WHO

HARR



THE EXAMINER  
**ISTJ**  
SEVERUS SNAPE

INTROVERTED | SENSING | THINKING | JUDGING

DEFINED BY THEIR HONOR AND DUTY. TAKE ANY TASK SERIOUSLY AND GIVE IT ALL THEIR ENERGY. THEY ARE NOT AFRAID TO WORK ALONE, BUT CAN MAKE GREAT TEAM MEMBERS IF THE NEED ARISES. DEEPLY VALUE TRADITIONS AND LOYALTY AND OFTEN PUT DUTY BEFORE PLEASURE.



THE DEI  
**IS**  
NEVILLE LONG

INTROVERTED | TRADITIONAL  
GIVER | FEELER | JUDGING

IS THERE A SPOT ON YOUR ASS THAT I HAVEN'T KISSED YET?  
Please, let me remedy that.



THE CRAFTSMAN  
**ISTP**  
HARRY POTTER

INTROVERTED | SENSING | THINKING | PERCEIVING

FIERCELY INDEPENDENT, ADVENTURERSON. DON'T LIKE MUCH ATTENTION. MORE INTERESTED IN THEIR OWN THINGS. DON'T LIKE TO FOLLOW THE RULES. LIVE IN RULES AS THEY PROHIBIT THEIR ABILITY TO DO THEIR OWN THING. ORGANIZE FACTS USING LOGICAL PRINCIPLES AND VALUE EFFICIENCY.



INTROVERTED | QUIET, FRIENDLY AND COMMITTED | FEELER | JUDGING

THE PERFECT  
**ISFJ**  
FRED & GEORGE

FREE HUGS FOR EVERYBODY!!!



THE PROMOTER  
**ESTP**  
GINNY WEASLEY

INTROVERTED | FLEXIBLE | ENTHUSIASTIC | FIGHTING

FLEXIBLE AND FIGHTING; THEY WANT TO ACT IMMEDIATELY TO SOLVE THEIR PROBLEMS. USES THEIR QUICK WIT AND CLEVERNESS. EXCEL AT SPONTANEOUSLY CHANGING PLANS. ENJOYING PHYSICAL ACTIVITY AND EXCITING, AND ESPECIALLY THRIVE ON THE SPIRIT OF COMPETITION.



INTROVERTED | OUTGOING | FANT LOVERS OF FORTS. ENJOY THE SPOTLIGHT AND SPONTANEOUS PEOPLE AND IDEAS

**ESTJ**



THE SUPERVISOR  
**ESTJ**  
MINERVA McGONAGALL

EXTROVERTED | SENSING | THINKING | JUDGING

PRACTICAL, REALISTIC, MATTER-OF-FACT, AND QUICK TO IMPLEMENT DECISIONS. ORGANIZE PROBLEMS AND TACKLE THEM WITH A PRACTICAL APPROACH. GETTING RESULTS IN THE MOST EFFICIENT WAY POSSIBLE AND TAKE CARE OF ROUTINE DETAILS. FORCEFUL IN IMPLEMENTING THEIR PLANS.



EXTROVERTED | WARMHEARTED WANT HARMLESSNESS, FRIENDSHIP WITH OTHERS AND ON THE DAY-TO-DAY

**ESTP**

ARTWORK: MAKANI.D



**ESFJ**

Is there a spot on your ass that I haven't kissed yet?  
Please, let me remedy that.



**INTP**

Say goodbye to all your **ISTJ** problems.

**STAR**

**ISTJ**

Owen Lars

**ISFJ**

C-3PO

The Inspector

Responsible, loyal, and hard working. Have an acute sense of right and wrong and work to preserve established norms and traditions. Somewhat reserved and prefer to work alone, but can make great team members if the need arises. Characterized by the ability to work hard and make sacrifices to keep society running smoothly.

**ISTP**

Chewbacca

The Crafter

Independent and adventurous, yet quiet and reserved. Interested in how and why things work. Adaptable and spontaneous. Live in the moment and attend to their peers and to their own personal systems, but not overly concerned with respecting rules if they get in the way. Characterized by their ability to get things done.

**ESTP**

Han Solo

The Promoter

Friendly, adaptable, and action-oriented "doers" who are focused on immediate results. Think on their feet and thrive in crises. Informal risk-takers who live fast-paced lives. Never allow rules to get in the way of their ambitions. Straightforward and realistic, take criticism well. Characterized by their ability to get things done and work well with others.

**ESTP**

Darth Vader

The Supervisor

Practical, realistic, organized, and strategic. Possesses natural leadership qualities. Strict boundary setters who take personal responsibility very seriously. Intensely focused on getting results and seek ways to do so in the most efficient way possible. Characterized by their ability to preserve traditions and provide security for their loved ones.

**ESTP**

Jar Jar Binks

The Inspector

**ISTJ**

Nonchalantly side-stepping your bullshit since the dawn of time.

**EN**

Take your pick: sugar or

**EN**

Take your pick: sugar or

Who's your character?

**NT**

Visioning

# MBTI in LOVE

**ENFJ**



"Anything to please you."

**INFJ**



"You are perfect."

**INTJ**



"I will fix you."

**ENTJ**



"Come away with me."

**ENFP**



"I love you, and you, and you."

**INFP**



"You're my only dream."

**INTP**



"Loving you is easy."

**ENTP**



"Grow old with you."

**ESFP**



"Let's enjoy the moment."

**ISFP**



"Runs away."

**ISTP**



"I like you now."

**ESTP**



"You know you love me."

**ESFJ**



"I cherish you."

**ISFJ**



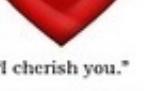
"Unconditionally."

**ISTJ**



"My pledge of love cannot be broken."

**ESTJ**



"I do."

