25th anniversary
annual INCOSE
international symposium
Seattle, WA
July 13 - 16, 2015

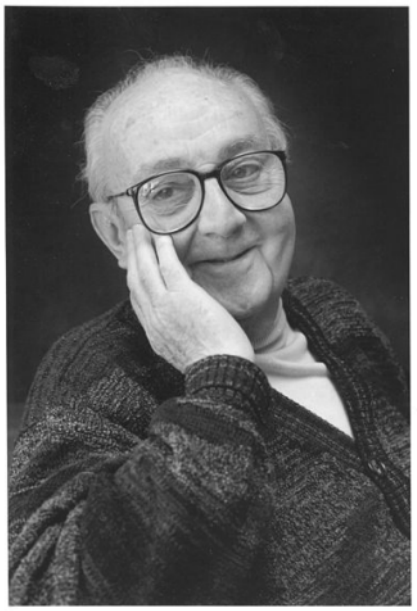
An Integral Approach to Systems Engineering

Kevin Devaney
SRC, Inc.

Models

Essentially, all models are wrong, some models are useful.

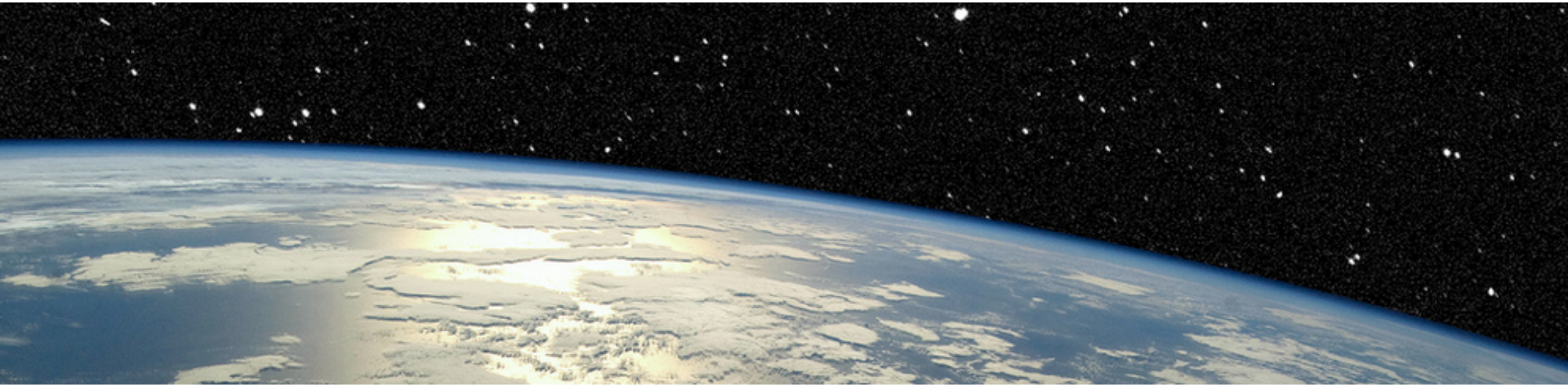
– George E. P. Box (1919-2013)



George E.P. Box

The Claim

- Integral Theory models are useful for SE
  - Broaden the perspective of SE
  - Improve how SE is practiced
  - Develop better solutions



Earth Horizon

Agenda

- Introduction to Integral Theory
- IT models and applications
  - Four quadrant model
  - Levels of development model
  - Complexity model (holons)
- Summary and conclusions

	Interior	Exterior
Individual	Upper Left (UL) I Intentional (Subjective)	Upper Right (UR) IT Behavioral (Objective)
Collective	Lower Left (LL) WE Cultural (Intersubjective)	Lower Right (LR) ITS Social (Interobjective)

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Integral Theory

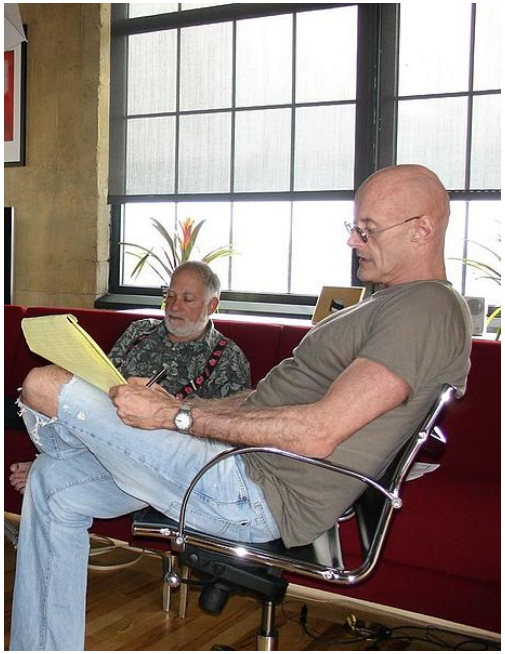
$$\iiint_V \nabla' \cdot \{\mathbf{J}(\mathbf{r}')G(\mathbf{r},\mathbf{r}')\}\, dv' = \oiint_{S_c} G(\mathbf{r},\mathbf{r}') \left[\mathbf{J}(\mathbf{r}') \cdot \hat{n}(\mathbf{r}')\right] ds'$$

Not a mathematical theory

Integral Theory is about the integration of knowledge

Integral Theory

- School of philosophy founded by Ken Wilber (1970's)
  - Work discussed today from 1995
  - Not widely known
- Goal to integrate all knowledge into a single framework
  - General and comprehensive
  - Applied to over 35 domains



Ken Wilber

Integral Theory Models

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Individual	Upper Left (UL) I Intentional (Subjective)	Upper Right (UR) IT Behavioral (Objective)
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Four Quadrant Model

Level	Color	Perspective
Post Integral	Turquoise	Kosmocentric
Integral	Teal	Planetcentric
Post Modern	Green	Worldcentric
Modern	Orange	Sociocentric
Traditional	Amber	Ethnocentric
Tribal	Red	Egocentric

Levels of Development Model

Biosphere
Ecosystem
Community
Population
Organism
Organ system
Tissue
Cell
Macromolecular
Molecule
Atom

Model of Complexity (Holons)

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Four Quadrant Model

	Interior	Exterior
Individual	Subjective Perspectives	Objective Perspectives
Collective		

Four Quadrant Model

	Interior	Exterior
Individual	Singular Perspectives	
Collective	Group Perspectives	

Upper Right
Individual / Exterior

	Interior	Exterior
Individual		• Objective • Measurable • Behaviors
Collective		

Lower Right
Collective / Exterior

	Interior	Exterior
Individual		
Collective		• Systems • Networks • Social systems • Systems of systems

Upper Left
Individual / Interior

	Interior	Exterior
Individual	• Thoughts, emotions • Perceptions • Beauty • Individual values	
Collective		

Lower Left
Collective / Interior

	Interior	Exterior
Individual		
Collective	• Shared values • Shared meaning • Culture • Ethics	

Four Quadrant Model

	Interior	Exterior
Individual	I	IT
Collective	WE	ITS

Four Quadrant Model

	Interior	Exterior
Individual	Upper Left (UL) I Intentional (Subjective)	Upper Right (UR) IT Behavioral (Objective)
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Integral Theory View of SE

		Exterior
Individual		Upper Right (UR) IT Behavioral (Objective)
Collective		Lower Right (LR) ITS Social (Interobjective)

- SE sees only the right-hand exterior perspective
  - Only the measurable, objective world matters
- Left-hand interior quadrants largely ignored
  - Most parts seen as having little value
  - Some parts mapped into right-hand quadrants

Flatland

		Exterior
Individual		Upper Right (UR) IT Behavioral (Objective)
Collective		Lower Right (LR) ITS Social (Interobjective)

Air Pollution

- Wilber calls this limited perspective “flatland”
- A fundamental cause of the world’s problems

Photo credit: National Park Service / Public domain

Use All Four Quadrants

	Interior	Exterior
Individual	Upper Left (UL) I Intentional (Subjective)	Upper Right (UR) IT Behavioral (Objective)
Collective	Lower Left (LL) WE Cultural (Intersubjective)	Lower Right (LR) ITS Social (Interobjective)

Four Quadrant Model

- Potential applications
  - Requirements and design
  - Verification and validation
  - CMMI and agile

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Requirements and Design

		Exterior
Individual		Upper Right (UR) IT Behavioral (Objective)
Collective		Lower Right (LR) ITS Social (Interobjective)

- SE tends to only see objective requirements
  - Focus on what is measurable
- We tend not to see the left hand side
  - For example, things like beauty, usability and culture

Steve Jobs and Apple

- Shows the value of left-hand quadrants in designing products
- Emphasis on beauty and people-friendly products

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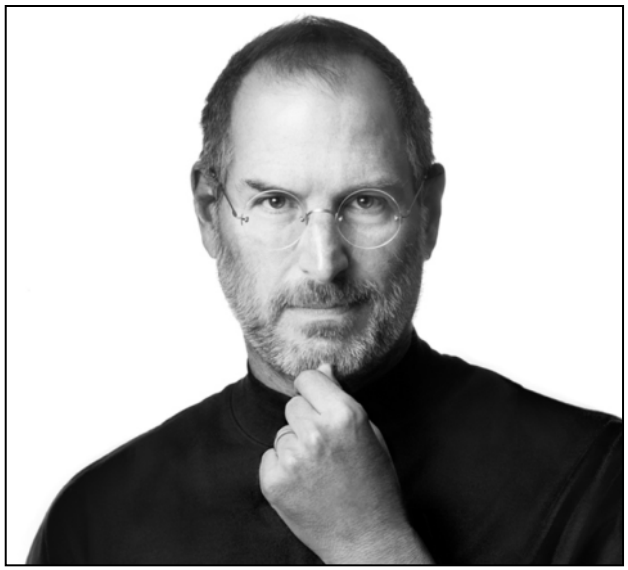

Steve Jobs

Photo credit: Mark Guadalupe / CC-BY-2.0

Apple vs IBM

Left-Hand, Subjective	Right-Hand, Objective
Apple Computers	IBM PCs and clones Microsoft Windows
User Experience	System Peformance CPU Speed RAM, Disk Space

Jobs' Design Principles

- Craftsmanship
  - Emphasis on craftsmanship and creating beautiful products
- Empathy
  - Make an intimate connection with the feelings of the customer
- Focus
  - In order to excel, eliminate everything that is not important
- Image
  - Everything you do must be congruent with the company image
- User-friendliness
  - Build user-friendly high-tech products
- Metaphors
  - Use metaphors that are part of the culture and easily understood

Steve Jobs introducing iPad

Photo credit: Matt Buchanan / CC-BY-2.0

Design Principles from *Fast Company* blog
Cliff Kuang, 2011

Jobs' Design Principles

	Interior	Exterior
Individual	I - Perspective of Experiences - Craftsmanship, beauty - Friendliness	IT - Perspective of Behaviors - Focus
Collective	WE - Perspective of Culture - Empathy, connection to customer - Impute, congruence with company image - Metaphors, leveraging existing cultural symbols	ITS – Perspective of Systems

Military Systems

SPS-48 Radar

Photo credit: US Navy / Public domain

Joint Strike Fighter

X-32

Photo credit: US Air Force / Public domain

X-35

Photo credit: US Navy / Public domain

Joint Strike Fighter

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Photo credit: US Air Force / Public domain

Joint Strike Fighter

X-35

Photo credit: US Navy / Public domain

Flatland in Architecture

		Exterior
Individual		Upper Right (UR) IT Behavioral (Objective)
Collective		Lower Right (LR) ITS Social (Interobjective)

Solar Decathlon Building

- Dr. Mark DeKay, University of Tennessee
  - *Integral Sustainable Design (2011)*
- Energy efficient / LEED-certified buildings
  - Emphasis on the technical aspects
  - Ignore subjective aspects (e.g. beauty)

Photo credit: F Delventhal / CC-BY-2.0

Integral Sustainable Design

	Interior	Exterior
Individual	Upper Left (UL) I Intentional (Subjective)	Upper Right (UR) IT Behavioral (Objective)
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Solar Umbrella House

- Use all four quadrants
  - Include subjective aspects of design
  - Include beauty, culture, connection with nature
  - Not only save energy, but instill environmental values

Photo credit: Calder Olivier / CC BY-SA 3.0

Four Quadrant Approach

	Interior	Exterior
Individual	I - Perspective of Experiences Shape Form to Engender Experience - Beauty and aesthetics - Experience of nature's cycles, processes, forces	IT - Perspective of Behaviors Shape Form to Maximize Performance - Energy, water, materials efficiency - LEED rating system
Collective	WE - Perspective of Culture Shape Form to Manifest Meaning - Connection to nature - Local myths & rituals	ITS – Perspective of Systems Shape Form to Guide Flow - Fitness to site & context

Four Quadrant Model

- Potential applications
  - Requirements and design
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Verification and Validation

	Interior	Exterior
Individual	Validation	Verification
Collective		

Verification and Validation

- How de we validate fuzzy requirements?
- Allow subjectivity in validation
- Each quadrant has its own methods of validation

	Interior	Exterior
Individual	Experience - Use perception and judgment - We can agree on subjective experiences of quality and beauty	Performance - Use performance criteria - Measure, calculate or model
Collective	Culture - Collective interpretation - Jury of experts	Flow - Use mappings to analyze flows

V&V in Architecture

	Interior	Exterior
Individual	Experience - Use perception and judgment - We can agree on subjective experiences of quality and beauty	Performance - Use performance criteria - Measure, calculate or model
Collective	Culture - Use collective interpretation - Jury of experts	Flow - Use mappings to analyze flows

Four Quadrant Model

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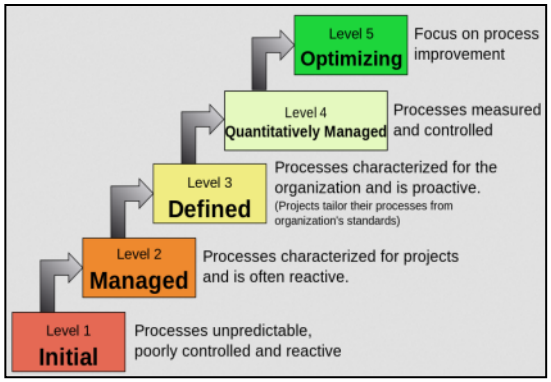
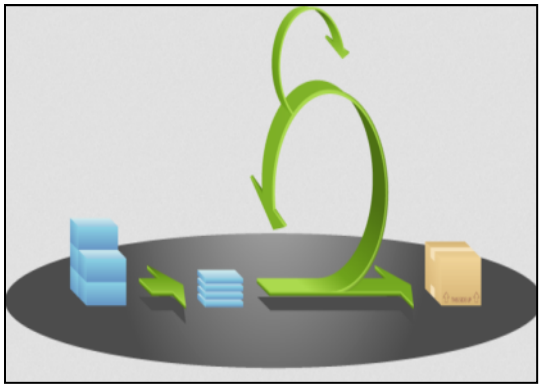
CMMI vs Agile Methodologies

- CMMI
  - Plan-oriented
  - Rigorous
  - Document-heavy
- Agile
  - Iterative
  - Lightweight



CMMI Maturity Levels

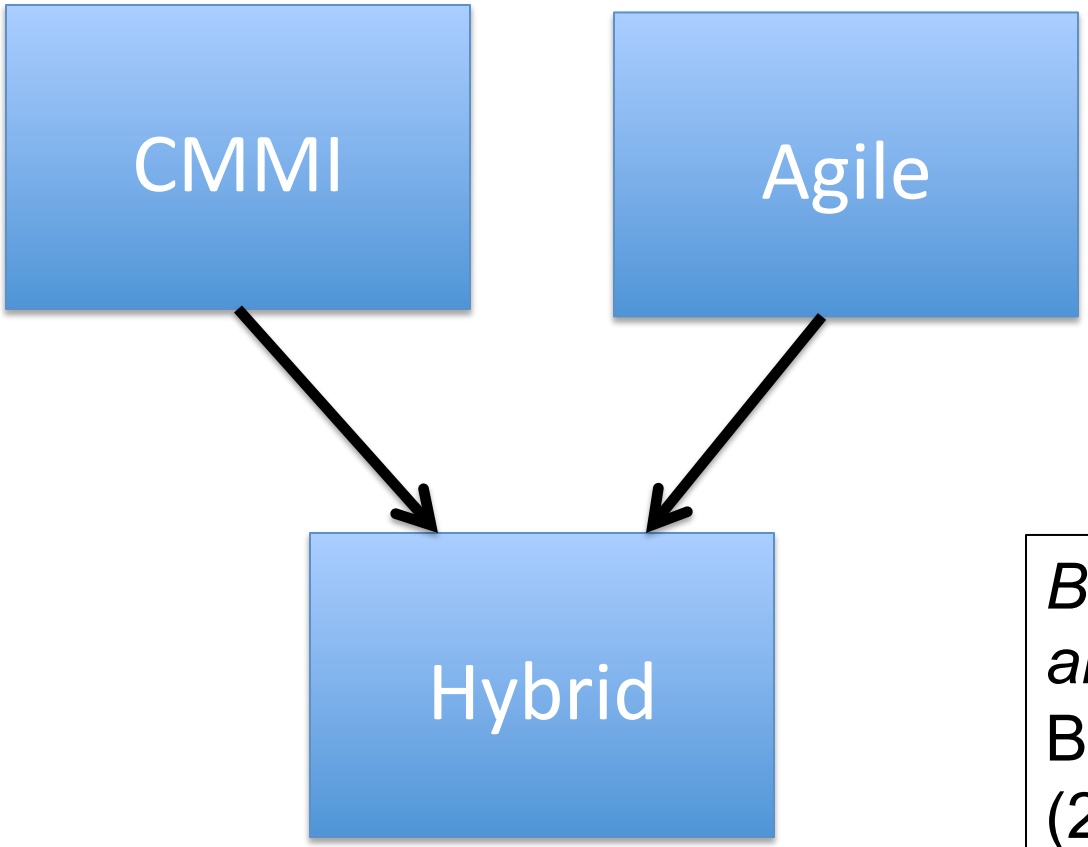
Image credit:
NASA
Public domain



Scrum Diagram

Image credit:
Mountain Goat Software/ CC BY 2.5

Integral Approach



Balancing Agility and Discipline, Boehm and Turner (2004)

CMMI = Flatland

		Exterior
Individual		IT - Processes and procedures - Measurement and analysis
Collective		ITS

Manifesto for Agile Software Development

We are uncovering better ways of developing
software by doing it and helping others do it.
Through this work we have come to value:

Individuals and interactions over processes and tools
Working software over comprehensive documentation
Customer collaboration over contract negotiation
Responding to change over following a plan

That is, while there is value in the items on
the right, we value the items on the left more.

From http://agilemanifesto.org/

Agile Model

	Interior	Exterior
Individual	I - Individuals	IT - Processes - Tools - Documentation - Responding to change - Following a plan
Collective	WE - Interactions - Customer collaboration	ITS - Working software - Contract negotiation

Integral Approach

	Interior	Exterior
Individual	I - Craftsmanship - Domain knowledge - Leadership - Skill level	IT - Documentation - Metrics - Processes and procedures
Collective	WE - Accountability - Conflict management - Culture - Customer focus - Discipline - Trust	ITS - Organizational structure - Process integration - Tools

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Levels of Development

Level	Color	Perspective
Post Integral	Turquoise	Kosmocentric
Integral	Teal	Planetcentric
Post Modern	Green	Worldcentric
Modern	Orange	Sociocentric
Traditional	Amber	Ethnocentric
Tribal	Red	Egocentric

- Mankind moving to higher levels of consciousness or development
- Moving up implies
  - Increasing perspective and decreasing egocentrism
  - Wider and longer term perspectives

Applications of Levels of Development

Level	Color	Perspective
Post Integral	Turquoise	Kosmocentric
Integral	Teal	Planetcentric
Post Modern	Green	Worldcentric
Modern	Orange	Sociocentric
Traditional	Amber	Ethnocentric
Tribal	Red	Egocentric

Application	Basic Idea
Organizational Development	Technical orgs tend to be at the Orange level ("Flatland"). Potential for higher performance at Integral/Teal level.
Leadership Development	Organizations cannot get to a higher level than their leaders. Develop leaders using Integral models.
Project Management	Use management practices from Integral/Teal organizations to improve project management.

Modern / Orange Organizations

Category	Description
Characteristics	Goal is to beat the competition, achieve profit and growth. Innovation is the key to staying ahead. Management by objectives.
Examples	Multinational companies Charter schools
Key Breakthroughs	Innovation Accountability Meritocracy

Integral / Teal Organizations

Category	Description
Characteristics	Less driven by fear and ego. Inner rightness as a compass. Mission oriented vs. goal-oriented. Build on people's strengths.
Examples	AES Patagonia
Key Breakthroughs	Self-organizing Wholeness Evolutionary purpose

Integral/Teal Organizations

- Study of Teal organizations by Frederic Laloux (*Reinventing Organizations, 2014*)
- Teal organizations achieve higher growth and stronger financial performance than their peers
- Some of the advantages of Teal organizations:
  - Stronger purpose
  - Wider distribution of power
  - Greater learning
  - Better use of talent
  - Less energy devoted to unproductive activities (e.g. meetings and compliance)

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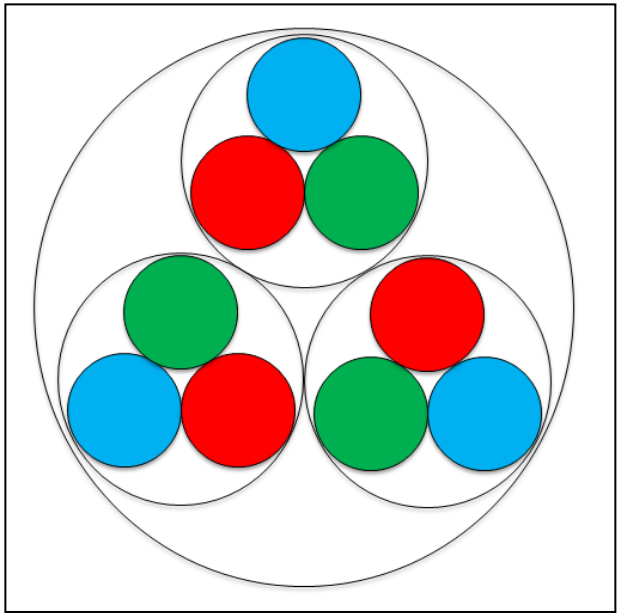
Model of Complexity

- Everything consists of holons
  - A whole by itself
  - A part of some larger whole



Biosphere
Ecosystem
Community
Population
Organism
Organ system
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Macromolecular
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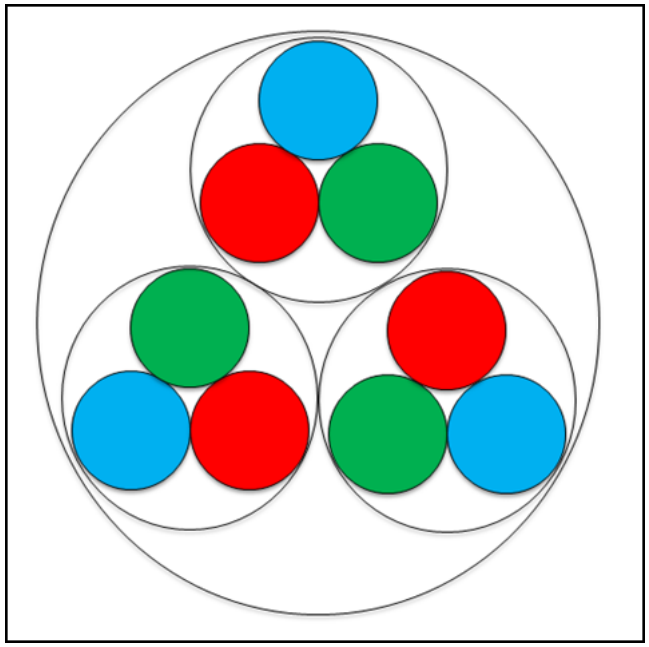
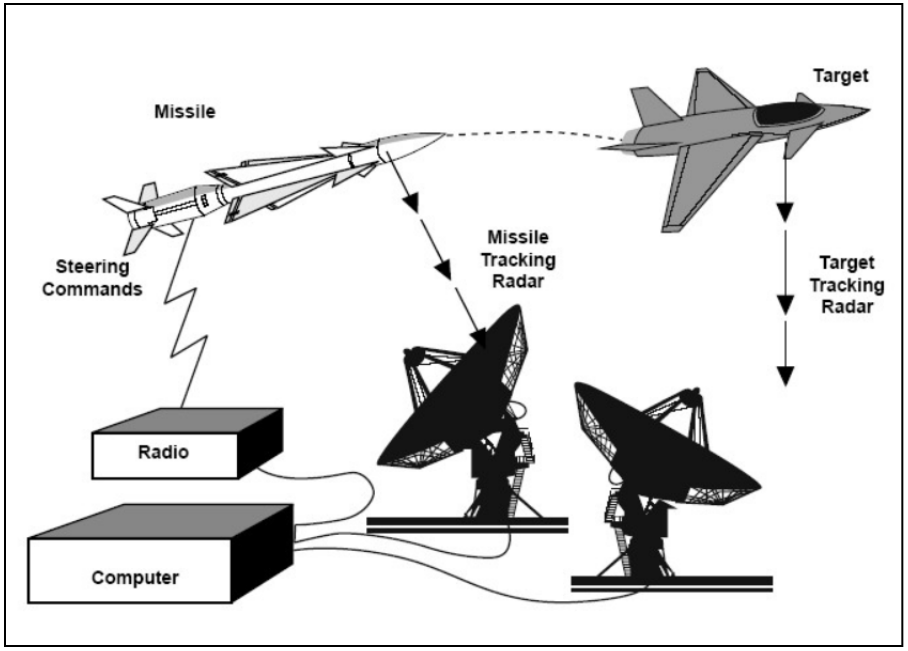
Atom

Holons and Systems of Systems



Holons



System of Systems

Image credit: Defense Acquisition University / Public Domain

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Rethink Subjectivity

- Subjectivity exists in SE
  - "ilities"
    - Usability, maintainability, etc.
  - Requirements quality
    - Clear, concise, correct, etc.
  - Estimating technical risk
    - Probability of occurrence, impact
- All four perspectives are always present
  - Subjectivity is everywhere
  - Deal with each quadrant on its own terms

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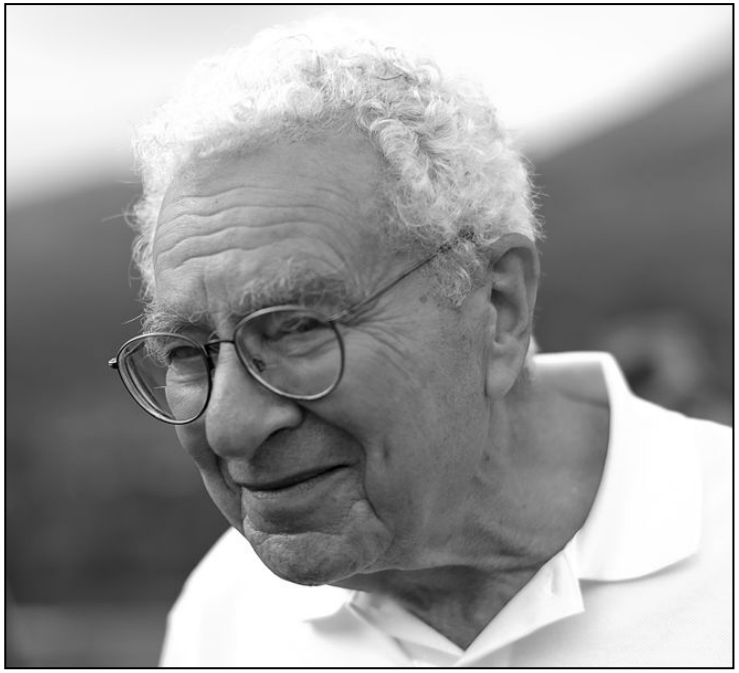
Beauty Matters

"In fundamental physics, a beautiful or elegant theory is more likely to be right than a theory that is inelegant" – Murray Gell-Mann (TED 2007)



Murray Gell-Mann

Photo credit: Joi Ito / CC BY 2.5

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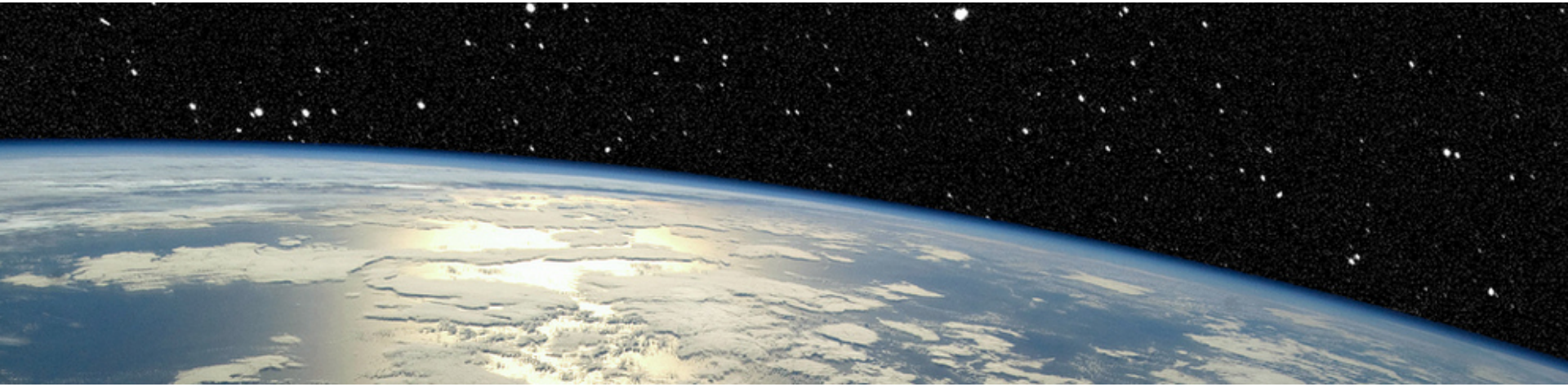
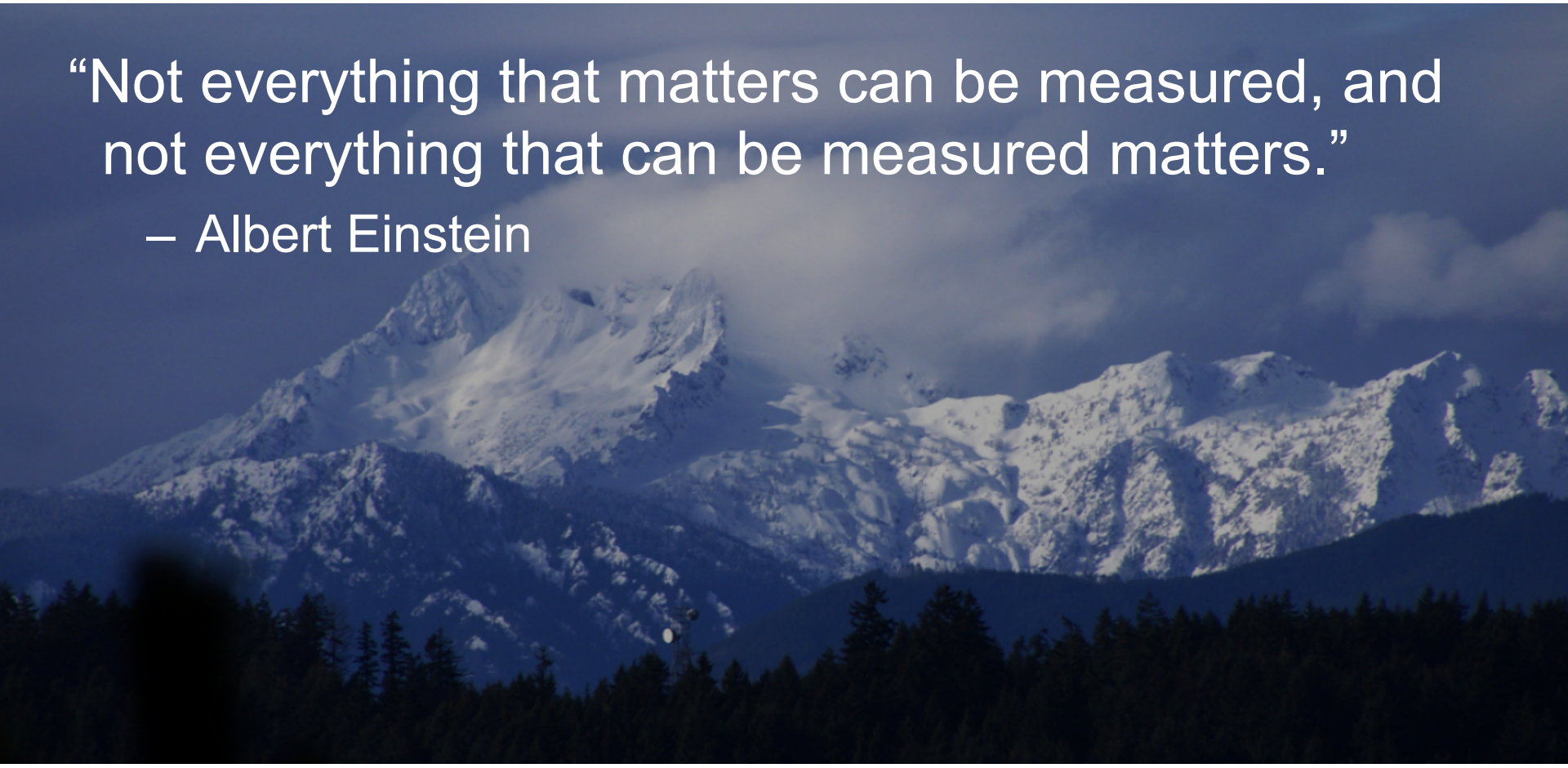


Earth Horizon

"Not everything that matters can be measured, and not everything that can be measured matters."

– Albert Einstein



Olympic Mountains

Photo credit: RVWithTito.com/ CC BY 2.0

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Thanks

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- The INCOSE IS reviewers

Thank you for listening.

Any questions or comments?

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