STAR

TEACHING TOP-DOWN APPROACHES TO THE ENGINEERING DESIGN PROCESS

Author: Joshua E. Katz
Mentor: Paulo Younse

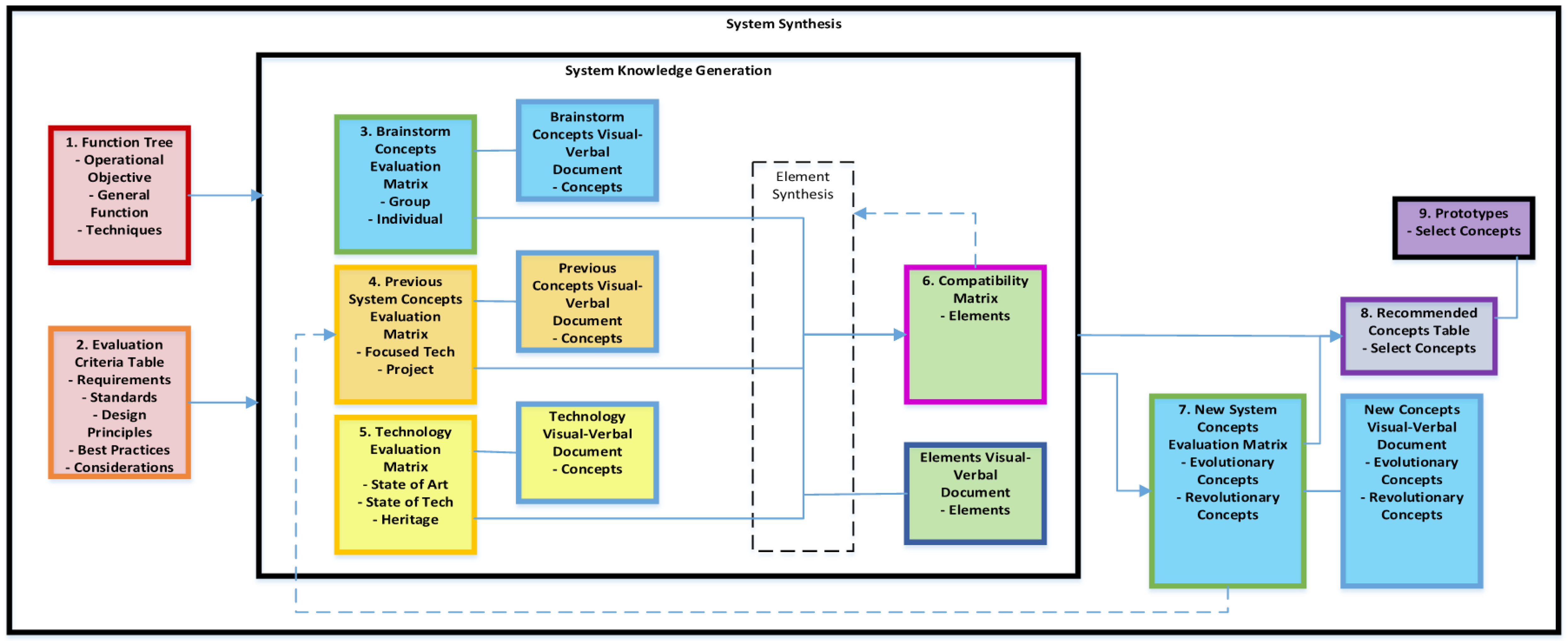
OBJECTIVES

Apply System Architecture Methodology to field of education.

Apply System Architecture Methodology to manufacturing of CCRS (Capture Containment Return System).

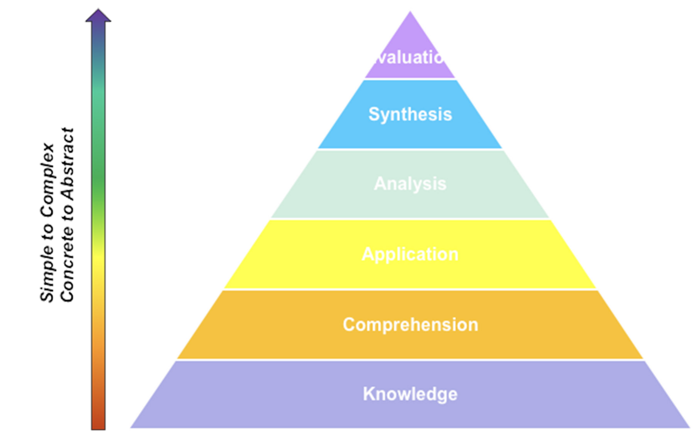
Apply educational and cognitive psychologies to System Architecture Methodology.

SYSTEM ARCHITECTURE METHODOLOGY



Creativity Stages	Formulate Problem	Acquire Relevant Knowledge	Acquire Related Information	Combine Ideas	Incubation/ Generate Ideas	Select Best Ideas	Externalize Ideas	
Tools	Function Tree	Evaluation Criteria Table	Discovered Systems Evaluation Matrix	Synthesized Systems Evaluation Matrix	System Concepts Visual-Verbal Document	System Elements Visual-Verbal Document	Compatibility Matrix	Recommended Concepts Table

Bloom's Taxonomy (1956)



			Cognitive Process																		
			Category	1 Remember		2 Understand							3 Apply		4 Analyze			5 Evaluate		6 Create		
				1.1	1.2	2.1	2.2	2.3	2.4	2.5	2.6	2.7	3.1	3.2	4.1	4.2	4.3	5.1	5.2	6.1	6.2	6.3
	Category	Subcategory	Subcategory	Recognizing	Recalling	Interpreting	Exemplifying	Classifying	Summarizing	Inferring	Comparing	Explaining	Executing	Implementing	Differentiating	Organizing	Attributing	Checking	Critiquing	Generating	Planning	Producing
Knowledge	A Factual	AA	Terminology	X																		
		AB	Specific Details/Elements	X			X	X	X	X					X				X			
	B Conceptual	BA	Classifications/Categories		X			X														
		BB	Principles/Generalizations			X	X								X				X			
		BC	Theories/Models/Structures																X			
	C Procedural	CA	Subject-specific Skills/Algorithms																			
		CB	Subject-specific Techniques/Methods					X	X										X	X		
		CC	Criteria for Procedure Use																			
	D Metacognitive	DA	Strategies																			
		DB	Cognitive Tasks																			
		DC	Self-knowledge																			

Bloom's Revised Taxonomy (2001)

DISCUSSION

This research was conducted over summer 2018 and continued over the summer of 2019 at the Jet Propulsion Laboratory, California Institute of Technology. The goal of the project was to apply the System Architecture Methodology to the engineering and education fields. During the summer of 2019, we ran weekly workshops for a select group of interns. Each week, we taught steps in the methodology, growing the interns' knowledge from the application to their projects. From these lessons, we hoped the interns advanced their creativity and comprehension of the design process. Bloom's Revised Taxonomy is utilized within all standards, objectives, and assessments in the curriculum.

RESULTS

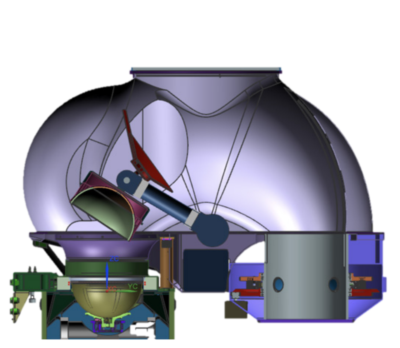
ROCS Selection Criteria Doc Last Update: Josh Katz 6-27-18		The technical data in this document is controlled under the U.S. Export Regulations; release to foreign persons may require an export authorization.		Criteria	Definition	Example of a Unsatisfactory System	Example of a Satisfactory System	Capture	Rationale
	1	Extrinsic Design Criteria	Environments	Radiation	The system is capable of surviving the ambient radiation conditions	Highly radiation sensitive material used	Outer shell is robust to radiation	4	The shell shape need to be maintained to have the OS transfe between section
	2	Intrinsic Design Criteria	System Resources	Mass	The overall mass of the system should be kept to a minimum	A shell exceeds the 13.7 kg mass. The volume made of solid steel	A capture volume made with a spacecraft aluminum or titanium	9	The total system mass has to meet the constraints for launch
	3			Volume	The volume of the system is kept to a minimum for stowed volume (KOV at launch)	Each external component doesn't link up the shell or cone	Structure meets the dimensions	7	The capture system shall stay withi the keep out volume
	4			Strength	The durability of the material is durable to withstand the impact of the OS	Structure gets damaged by the OS hitting it in the vacuum of space	Structural integrity stays in a constant shape without any shape altering	8	The structure has excellent integrit to hold shape if the OS rams into th shell
	5	Life Cycle Criteria	Fabrication	Producibility	The system is relatively simple to produce or manufacture in a timely manner	Maufucturing process takes too long	Maunfacturing process is easy and timley	8	The capture system shall be simple and cost effective to produce
	6		Operations	Accuracy	The system provides the necessary accuracy level required for the operation	The shell can't contain the OS while the arm is swinging	The shell sucessfuly contained the OS while alignment is going on	8	The shell needs to complete its mission to maintain the OS during alignment
	7	Effectiveness Criteria	Risk	Sensitivity to fabrication flaws	The system is capable of operating in spite of fabricator error	The shell is deformed	The shell meets the dimensions after fabrication	7	The production of the shell meets the parameters
	8	Programmatic Criteria	Project Impact	Production Cost	Cost should be kept to a minimum	The materials and production costs more than budgeted	The production and the materials are equal or under the budget	7	The capture system shall be obtainable within the budget
	9			Time	Production of the part is done in a timely manner	Time takes too long to produce	Time to maufacture takes less time than anticipated	8	The capture system shall be obtainable within time frame

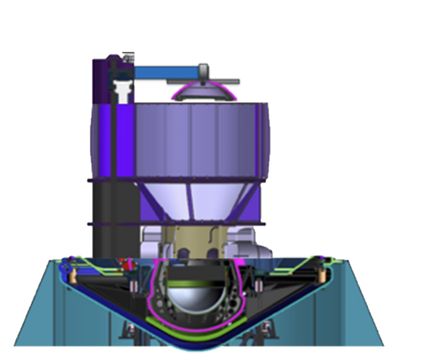
		System Element	Additive	Subtractive	Machining	Joining	Molding	Forming	Casting	Criteria	Environments: Radiation	System Resources: Mass	System Resources: Volume	System Resources: Strength	Fabrication: Producability	Operations: Accuracy	Risk: Sensitivity to fabrication flaws	Project Impact: Production Cost	Project Impact: Time	Normalized Concept Structure Score	Normalized Total Concept Score
System Concept										Weight	4	9	7	8	8	8	7	7	8		
	Wire Frame		1			1		1			4	5	5	1	4	4	4	4	4	0.776	0.74
	Joint Assembly (two halves?)		1	1	1	1			1		5	4	4	4	5	3	5	4	3	0.81	0.76
	Sheet Metal			1	1	1	1	1			5	4	4	3	5	4	5	5	4	0.85	0.79
	Elastic							1			5	5	4	2	3	3	3	3	3	0.68	0.66
	Composite		1								2	5	3	4	3	3	3	1	2	0.60	0.59
	Single (Monolithic)		1	1	1		1	1	1		5	3	5	5	2	3	1	1	1	0.56	0.6
Criteria		Weight																			
Environments	Radiation	4	4	5	5	5	5	5	5												
System Resources	Mass	9	4	4	4	4	2	4	1												
	Volume	7	5	5	5	4	3	3	3												
	Strength	8	3	4	4	4	4	2	5												
Fabrication	Producability	8	1	3	3	5	2	3	3												
Operations	Accuracy	8	4	4	4	4	2	3	2												
Risk	Sensitivity to fabrication flaws	7	3	4	4	5	2	3	2												
Project Impact	Production Cost	7	2	4	4	4	3	4	3												
	Time	8	1	2	2	5	3	3	4												
Normalized Element Score			0.6	0.8	0.8	0.9	0.6	0.6	0.6												

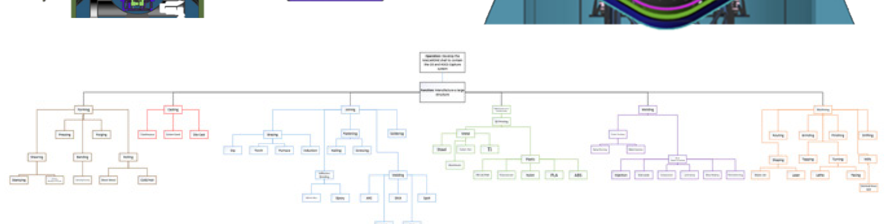
	System Element	Primary: Additive	Subtractive	Machining	Joining	Molding	Forming	Casting	Normalized Sum		Legend/Score	
Secondary	Additive	5	2	2	2	1	2	1	0.43	0.60	Positive Synergy	5
	Subtractive	5	5	5	3	5	5	5	0.94	0.81	N/A	4
	Machining	5	5	5	3	5	5	5	0.94	0.81	Independent	3
	Joining	5	5	5	5	5	5	5	1.00	0.79	Indeterminable	3
	Molding	2	2	2	3	5	2	2	0.51	0.64	Negative Synergy	2
	Forming	3	3	3	2	5	5	3	0.69	0.70	Not Compatible	1
	Casting	2	2	2	2	1	1	5	0.43	0.59		
		0.77	0.69	0.69	0.57	0.77	0.71	0.74				

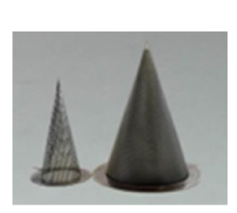
Cone Structure	Mass	Lead Time	Sensitivity to fabrication flaws	Strength	Production Cost	Rank
Joint Assembly (two halves?)	~19 kg	Short	Less	Strong	Middle	1
Wire Frame	Less 10 kg	Short	Less	Weak	Cheap	2
Sheet Metal	~19 kg	Medium	Middle	Middle	Cheap	3
Composite	14.7 kg	Long	More	Middle	Expensive due to mixing different materials together	4
Single (Monolithic)	14.343 kg	Long	More	Strong	Expensive due to weight and machining	5

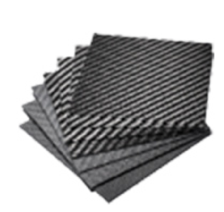
APPLICATIONS

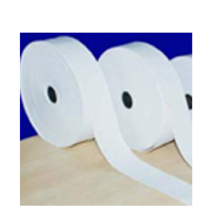


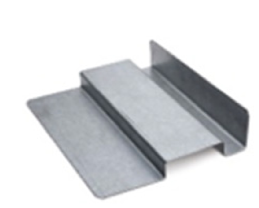




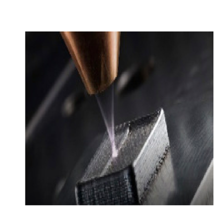








State-of-the-Art



State-of-Technology

H.S. ENGINEERING DESIGN

Students who demonstrate understanding can:

HS-ETS1-1. Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants

HS-ETS1-2. Design a solution to complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

HS-ETS1-3. Evalutate a solution to a complex real-world problem based on prioritized criteria and trade-offs that ccount for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.

HS-ETS1-4. Use a computer simulation to model the impact of proposed solutins to a complex real-world problem with numerous criteria and constrains on interactions within and between systems relevant to the problem.

REFERENCES

Anderson, L. W., Krathwohl, D. R., & Bloom, B. S. (2001). A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives. New York: Longman.

Mayer, R. E. (2011). Applying the science of learning. Boston, MA: Pearson/Allyn & Bacon.

Younse, P., Strahle, J. W., Lalla, K., Dolci, M., Ohta, P., & Adajian, R. (2018, March 10). A System Architecting Methodology Using Bloom's Taxonomy to Promote Creative Engineering Synthesis [Digital image]. Retrieved from https://www-robotics.jpl.nasa.gov/people/Marco_Dolci/publications.cfm

Younse, P., Strahle, J. W., Dolci, M., Ohta, P., & Lalla, K. (2018, March 10). An Orbiting Sample Capture and Orientation System Architecture for Potential Mars Sample Return [Digital i mage]. Retrieved from https://www-robotics.jpl.nasa.gov/people/Marco_Dolci/publications.cfm

ACKNOWLEDGEMENTS

The 2019 STEM Teacher and Researcher Program and this project have been made possible through support from Chevron (www.chevron.com), the National Science Foundation through the Robert Noyce Program under Grant #1836335 and 1340110, the California State University Office of the Chancellor, and California Polytechnic State University in partnership with Jet Propulsion Laboratory, California Institute of Technology and Illinois State University. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the funders.

Chevron

CAL POLY
SAN LUIS OBISPO

Jet Propulsion Laboratory
California Institute of Technology