ARIZONA STATE UNIVERSITY

SCHOOL OF SUSTAINABLE ENGINEERING AND THE BUILT ENVIRONMENT

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Summary of Allenby's ESEM Principles

Tom Roberts

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Ira A. Fulton Schools of Engineering

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In his writings over the past decade, Brad Allenby has proposed (at least) 16 principles of sustainable engineering (see references) that are collectively known as the Earth Systems Engineering and Management (ESEM) principles. These principles have merit and applicability in many disciplines and domains of discourse, but are sometimes awkward to use due to the quantity of words required to accurately express their meaning. In light of this, it has become necessary to formulate a simplified list of "abbreviated tags" for ease of reference in conversation and concise writing. This list of tags also makes the principles immediately accessible to those who may want to pursue the more thorough definitions offered by Allenby. The following tags have been proposed for use when a concise phrasing is required. The citation provided after the tag is, in my opinion, the most complete expression of Allenby's thought on this principle. It can be used when citing the principle in written assignments or publications.

1. Targeted Intervention (Allenby, 2012, p. 356)
2. Evaluate Technological Fix (Allenby, 2012, p. 357)
3. Real-World Boundaries (Allenby, 2012, p. 359)
4. Multi-dimensional Dialogue (Allenby, 2005, p. 185)
5. Techno-Social Differentiation (Allenby, 2005, p. 185)
6. Transparent Governance (Allenby, 2012, p. 363)
7. Multicultural Dialogue (Allenby, 2012, p. 364)
8. Part of the System (Allenby, 2012, p. 361)
9. Systems and Artifacts (Allenby, 2012, p. 374)
10. Continuous Learning (Allenby, 2012, p. 367)
11. Long-term Investment (Allenby, 2005, p. 187)
12. Quantitative Metrics (Allenby, 2012, p. 368)
13. No Explicit Control (Allenby, 2012, p. 369)
14. Expect Emergence (Allenby, 2005, p. 187)
15. Incremental and Reversible (Allenby, 2012, p. 370)
16. Resilient not Redundant (Allenby, 2012, p. 370)

The table below presents these tags alongside snippets of the extended formulations of the principles in Allenby's words. Interestingly, this also reflects the evolution of his thought over the years—but mostly reinforces the impression that they have not changed that much. They are arranged as simply as possible according to some of the early lists published. The most recent (partial) listing (from *Techno-Human Condition*) is included but the target audience of that book dictated a unique approach to their expression. Still it is easy to see the similarities.

Allenby's ESEM principles have no implementation order required or implied. They are all equally important, though depending on the application, they may not all be equally relevant. In fact, in keeping with the complexity of the systems they purport to manage, they all must be applied simultaneously, or severally, as necessary to analyze and manage the target complex system. In his published lists, Allenby has loosely organized the principles into theoretical, governance, and design categories, but these categories are, in general, only of limited interest in most uses of the principles. Still, these categories are preserved in the table below with notes indicating when a principle has migrated into another category due to evolution in Allenby's thought. On occasion, Allenby has also numbered the principles, but the ***numbers should not be used*** as a reliable reference since they have changed over time.

Note that the tags proposed for these principles are useful, but they are not necessarily approved by Allenby. Any confusion they introduce is entirely the fault of this author.

Roberts Tag	*IEEE Tech. and Society: ESEM paper,* Allenby, 2000	*Reconstructing Earth,* Allenby, 2005	*Environmental Science & Technology: ESEM Manifesto,* Allenby, 2007	*Theory and Practice of Sustainable Engineering,* Allenby, 2012	*Techno-Human Condition*, Allenby & Sarewitz, 2011
	Theory	**Theoretical Principles**	(ungrouped/un-numbered)	**Theoretical Principles**	(not categorized)
1. Targeted Intervention	1) Only intervene when necessary, and then only to the extent required (p. 22).	1. Intervene only when necessary, and then only to the extent required (p. 185).	Only intervene when necessary, and then only to the extent required.	1. Only intervene when necessary, and then only to the extent required (p. 356)	#5. lower the amplitude and increase the frequency of decisions (p. 164). #10. intervene early and often (p. 174). (see also *Incremental and Reversible* below) p. 90 “no one knows how to intervene....” (see *No Explicit Control* below) p. 105 *not* “attack with rigidity” but “explore with humility”
2. Evaluate Technological Fix	6) Major shifts in technologies and technological systems should be evaluated before, rather than after, implementation of policies and initiatives designed to encourage them (p. 22).	[Governance] 10. Major shifts in technologies and technological systems should, to the extent possible, be explored before, rather than after, implementation of policies and initiatives designed to encourage them (p. 187).	The capability to model and dialogue with major shifts in technological systems should be developed before, rather than after, policies and initiatives encouraging such shifts.	2. Major shifts in technological systems should be evaluated before, rather than after, implementation of policies and initiatives designed to encourage them (p. 357).	#1. eschew the quest for solutions (p. 162). #2. focus on option spaces (p. 162). #6. always question predictions (p. 165). #7. Evaluate major shifts in technological systems before, rather than after implementation of policies and initiatives designed to encourage them (p. 165). p. 57 “caution regarding any technological fix”

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3. Real-World Boundaries	5) Boundaries around ESEM initiatives should reflect real world couplings and linkages through time, rather than disciplinary or ideological simplicity. It cannot be overemphasized that ideology, whether explicit or implicit, inevitably is a (frequently inappropriate and dysfunctional) oversimplification of the systems at issue and their dynamics, and such approaches should be avoided to the extent possible (p. 22).	4. ESEM requires a systems-based approach, with analysis and boundaries reflecting real-world behavior and characteristics rather than disciplinary or ideological simplicity (p. 185). 5. the way problems are stated defines the systems involved. Accordingly, ideology will often be implicit in the way problems are defined, rather than explicit. [Boundaries drawn in this way result in oversimplification and do not] reflect real-world couplings and linkages through time (p. 185).	It is critical to be aware of the particular boundaries within which one is working and to be alert to the possibility of logical failure when one's analysis goes beyond the boundaries.	3. It is critical that the sustainable engineer be aware of the particular boundaries within which he or she is working, and to be alert to the possibility of logical failure when one's analysis goes beyond the boundaries (p. 359).	#6. always question predictions ("values brought out into the open" p. 165) #11. accept and nourish productive conflict ("periods of bounded conflict" p. 174). p. 40 "same artifact, different system boundaries implied by the analysis" p. 54 "general error" of boundary jumping p. 64 no apology for "fuzzy boundaries and some unavoidable arbitrariness" p. 109 "drawing boundaries around such systems is necessarily arbitrary" p. 110 and 121 ideologies as over-simplifying mechanisms p. 157 trouble bringing "boundaries into focus"
4. Multi-dimensional Dialogue	2) At the ESEM level, projects and programs are not just scientific and technical in nature, but unavoidably have powerful economic, political, and cultural dimensions; in many cases, ethical and even religious considerations will be important as well. An ESEM approach should integrate all these factors (p. 22).	2. ESEM projects and programs are highly scientific and technical in nature—but they also have powerful economic, political, cultural, ethical, and religious dimensions as well. All of these facets should be explicitly integrated into ESEM approaches (p. 185).	Implicit social engineering agendas and reflexivity make macroethical and value implications inherent in all ESEM activities.	6. Sustainable engineering at the earth systems level necessarily includes macroethical and worldview implications (p. 361).	#11. accept and nourish productive conflict (p. 174). p. 71 "technologies destabilize the world, changing cultures, worldviews, power relationships, and ethical, moral, and theological systems"

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5. Techno-Social Differentiation	3) Unnecessary conflict surrounding ESEM projects and programs can be reduced by recognizing the difference between social engineering — efforts to change cultures, values, or existing behavior — and technical engineering. Both need to be part of ESEM projects, but they are different disciplines and discourses, involving different issues and worldviews, and cannot be substituted for each other (p. 22).	3. ESEM projects often combine technical scientific and engineering issues and efforts to change behavior (social engineering). This is not necessarily inappropriate, but every effort should be made to differentiate between the two: the discourses, political contexts, and degrees of complexity involved are quite different (p. 185).		4. There is a difference between social engineering and technical engineering, and the sustainable engineer should not only understand, but should respect, that important difference (p. 359).	#9. Do not confuse economic efficiency with social efficiency (p. 167). [forced] p. 50 IVM example p. 52 the lure of technological fix: "the more responsibility for safety you can transfer" to technology "the safer the system will be" p. 167-8 Economic efficiency is enhanced by level I technology, but "social efficiency is a level III beast"
	Governance	**Governance Principles**		**Governance Principles**	
6. Transparent Governance	1) ESEM initiatives by definition raise important scientific, technical, economic, political, ethical, theological, and cultural issues in the context of an increasingly complex global polity. Given the need for consensus and long term commitment, the only workable governance model is one which is democratic, transparent, and accountable (p. 22).	6. ...need for consensus and transparency, which can be met only by governance processes that are open, democratic, transparent and accountable (p. 186).	Conditions characterizing the anthropogenic Earth require democratic, transparent, and accountable governance and pluralistic decision-making processes.	1. Conditions characterizing the anthropogenic Earth require democratic, transparent and accountable governance (p. 363).	#3. Pluralism is smarter than expertise (p. 163). #11. accept and nourish productive conflict (p. 174). p. 22 "the individual-rights perspective faces a serious scale-up problem"

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7. Multicultural Dialogue	2) If any ESEM project is to achieve public acceptance and social legitimacy, it must at all stages be characterized by an inclusive dialog among all stakeholders (p. 22).			2. Multiculturalism and dialog (p. 364).	#3. Pluralism is smarter than expertise (p. 163). #11. accept and nourish productive conflict (p. 174). p. 56 deaf culture example p. 118 "simultaneous contemplation of many different and perhaps conflicting worldviews"
8. Part of the System	[Design] 2) Rather than being exogenous to a system, the earth systems engineer will have to see herself or himself as an integral component of the system itself, closely coupled with its evolution and subject to many of its dynamics (p. 23). 3) ...ESEM governance structures should accordingly place a premium on flexibility, and the ability to evolve in response to changes in system state and dynamics, and *recognize the policymaker as part of an evolving ESEM system, rather than an agent outside the system guiding or defining it* (p. 23).	7. flexible and able to respond quickly and effectively to changes in a system's state and dynamics; this will require including the policy maker as part of an evolving ESEM system, rather than as an agent outside the system guiding or defining it (p. 186).	the actors and designers are also part of the system they are purporting to design, creating interactive flows of information (reflexivity) that make the system highly unpredictable and perhaps more unstable.	[Theoretical] 5. sustainable engineers are also part of the system they are purporting to design, creating a reflexivity that makes the system highly unpredictable and, to some extent, perhaps more unstable (p. 361).	p. 70 "the human itself is part of what we are changing..." and "the human... is increasingly shaped by our technologies" p. 100 "includes the human itself" p. 117 mental models should be adaptive "without cutting ourselves entirely loose from our cultural, political, and intellectual moorings"

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9. Systems *and* Artifacts	[Theory] 4) It follows from the above principles that ESEM requires a focus on the characteristics and dynamics of the relevant systems as systems, rather than just as the constituent artifacts. The artifacts will, of course, have to be designed in themselves as well; in this way, ESEM augments, rather than replaces, traditional engineering activities (p. 22).		We must learn to engineer and manage complex systems, not just artifacts.	The Final Principle: Engineer and manage complex systems, not just artifacts. "Embrace rigorous and principled muddle, rather than seeking false and ultimately dysfunctional simplicity" (p. 374).	This is essentially the theme of the entire book: wicked-complex systems. Complex technological and earth systems are made "wicked" by the human element (techno-human).
10. Continuous Learning	4) Continual learning at the personal and institutional level must be built into the process (p. 23).	8. it is particularly important to ensure that continual learning at the personal and institutional level is built into ESEM processes (p. 186).	Ensure continuous learning.	4. Ensure continuous learning (p. 367).	#8. Ensure continual learning (p. 167). p. 43 airline example p. 178 "continual process of reflecting"
11. Long-term Investment	5) There must be adequate resources available to support both the project, and the science and technology research and development which will be necessary to ensure that the responses of the relevant systems are understood (p. 23).	9. ensure that adequate resources, over time, are available for support of both the project and the associated science and technology research and development (p. 187).			

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	Design	**Design and Engineering**		**Design and Management**	
12. Quantitative Metrics	1) Know from the beginning what the desired (and reasonably anticipated) outcomes of any intervention are, and establish quantitative metrics by which progress may be tracked. Additionally, predict potential problematic system responses to the extent possible, and identify markers or metrics by which shifts in probability of their occurrence may be tracked.	12. establish quantitative metrics by which progress can be tracked. (for negative systems behavior as well) (p. 188).		1. establish metrics that determine whether the system is indeed moving along an appropriate path to achieve the desired outcomes (p. 368).	p. 51 "performance can be easily measured" and "feedbacks from failure are clear"
13. No Explicit Control	2) Unlike simple, well-known systems, the complex, information dense and unpredictable systems that are the subject of ESEM cannot be centrally or explicitly controlled.		Unlike simple systems, complex, adaptive systems cannot be centrally or explicitly controlled.	2. unlike simple systems, complex adaptive systems cannot be centrally or explicitly controlled (p. 369).	p. 90 "no one knows how to intervene...." (see *Targeted Intervention* above) p. 91 "...another category mistake trying to convince us that, by playing with a subsystem, we can change the larger system, and its emergent behavior, in ways that are *a priori* predictable and desirable. No can do."
14. Expect Emergence		11. emergent characteristics at high levels of system organization; evaluations of scale; scale-up should allow for the inevitable (especially in complex systems) discontinuities and emergent characteristics (p. 187).			#2. focus on option spaces (p. 162). #4. play with scenarios (p. 164).

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15. Incremental and Reversible	3) Whenever possible, engineered changes should be incremental and reversible, rather than fundamental and irreversible. In all cases, scale-up should allow for the fact that, especially in complex systems, discontinuities and emergent characteristics are the rule, not the exception, as scales change. Lock-in of inappropriate or untested design choices as systems evolve over time should be avoided.	13. policy, design and engineering initiatives in ESEM systems should be incremental and reversible, rather than fundamental and irreversible: "lock-in" of inappropriate or untested design choices should be avoided whenever possible (p. 188).	Whenever possible, engineered changes should be incremental and reversible, rather than fundamental and irreversible. Accordingly, premature lock-in of system components should be avoided where possible, because it leads to irreversibility.	3. Premature lock-in of system components should be avoided where possible (p. 369). 4. Whenever possible, engineered changes should be incremental and reversible, rather than fundamental and irreversible (p. 370).	#1. eschew the quest for solutions (p. 162). #2. focus on option spaces (p. 162). #4. play with scenarios (p. 164). #5. lower the amplitude and increase the frequency of decision making (p. 164). #10. intervene early and often (p. 174). p. 44 Level I technology lock-in because it is "simple, reliable, easy to understand" but then "not able to adjust when adverse Level II behaviors emerge" p. 93 incremental change that incorporates learning
16. Resilient not Redundant	4) An important goal in earth systems engineering projects should be to support the evolution of resiliency, not just redundancy, in the system.	14. ESEM should attempt to foster resilience, not just redundancy (p. 188).	aim for resiliency, not just redundancy, in design.	5. aim for resiliency, not just redundancy, in design (p. 370).	#2. focus on option spaces (p. 162). #4. play with scenarios (p. 164). p. 105 "build resilience and adaptability into our culture"

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