A Deeper Look at the Physics of Large Complex Projects

A Neo-classical Project Management Theory is Required[1]

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I have previously written about the transition that I believe is necessary in project management thinking related to large complex projects[2]. In those writing I describe the shift as analogous to the shift from Newtonian to relativistic physics[3]. Subsequently, I have compared the nature of large complex programs to open systems[4]. Reflecting back, classical project management theory was very much based on closed systems thinking and early applications of systems thinking to projects and engineering was also very much based on closed systems thinking.

This is analogous to the closed systems of Newton and Einstein's correction of his original General Theory of Relativity through the introduction of the cosmological constant to close a system which he believed behaved mechanistically and not expanding. In hindsight the cosmological constant was not necessary but does suggest some properties of the universe and became relevant in explaining an accelerating expansion of the universe. Subsequently, there was at least one special case where the deterministic nature of a closed system broke down when considering General Relativity suggesting at least some open nature to this system.

As I reflect on an open system analog for the universe a large complex project exists in, I will begin by attempting to create some thought equivalence between aspect of Einstein's work and subsequent physical theorems and large complex projects. It has been many years since I've used any of my nuclear engineering training so what follows may be overly simplistic for any one with serious training in physics.

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[2] Prieto, R. (2015). Theory of Management of Large Complex Projects; Construction Management Association of America; ISBN: ISBN 580-0-111776-07-9; October; https://www.researchgate.net/publication/299980338_Theory_of_Management_of_Large_Complex_Projects
[3] Prieto, R. (2015). Physics of Projects; PM World Journal Vol. IV, Issue V – May; https://www.researchgate.net/publication/275888028_Physics_of_Projects
[4] Large Complex Programs as Open Systems; National Academy of Construction Executive Insight; https://www.naocon.org/insights/

Relativistic Energy and Mass

At the most fundamental level for Einstein, relativistic energy (kinetic and potential energy) was associated with the photon. Mass represented the conversion of relativistic energy such that energy (E) times a conversion factor ($1/c^2$ in the case of special relativity) was equal to the mass resulting from the conversion of energy to a more tangible form. I have always thought of mass as "frozen" energy but more relevant here is the nature of mass created by the conversion of energy times a conversion factor. In the universe of large complex projects I think of energy as related to the work done by one person unit of work. The resultant output is the frozen energy of people if you will. Mass represents the tangible form of some units of work times a conversion factor. The conversion factor will more likely be analogous to Einstein's more general form found in General Relativity but we will return to that later.

So at the most fundamental level in a large complex project we have a source of energy (human work) that can through a defined process be translated into a tangible object or outcome (a mass equivalent).

Some Points to Consider

Before we move further into the use of the relativistic analogy a few points are worth highlighting. First, Einstein's inclusion of a cosmological constant derived from his view at the time that the universe was a closed system and not expanding. After the universe was found to indeed be expanding the cosmological constant was not required to close the system described by general relativity. Space time was unstable without the cosmological constant. Take it out and you have an expanding dynamic system that is changing overall but can have local regions of stability

Second, despite his Nobel Prize of 1921 related to light quanta, Einstein had trouble accepting the quantum nature since the quantum nature has fundamental indeterminism. Quantum mechanics is uncertain and creates a disorderly universe, not unlike the situation we often encounter with large complex projects.

Third, open systems show relatively fixed structures or reality and relatively open scopes for possibility. Open systems tend toward differentiation, growth in complexity and integration or networking with other systems. Open systems are also open to leaps in combinations resulting in new wholes. Think emergence. Catastrophic behaviors are part of their history.

Each of these three points will become important as we continue with this relativistic analogy.

Space-time

Let's return now to one of Einstein's central concepts, namely space-time. For Einstein the two parameters were linked and inseparable. Importantly, they are shaped by the presence of mass (m) but also the passing of energy through it. The later is most notable in the form of gravitational waves that transmit gravitational radiation, distorting local space-time as they transit it.

In large complex projects we progressively change the local nature of a project's "space-time" in several ways. Initially, we impact the project setting through the introduction of a significant amount of "potential energy" defining the proposed project and its implications and ramifications. This "potential energy" (one component of relativistic energy) has not yet been made tangible by transformation into kinetic energy and ultimately the mass of the project itself. But the concentrated presence of this relativistic energy component if you will has the effect of beginning to shape space-time. We see this in the induced responses in space-time by the introduction of this local distortion. Stakeholder concerns emerge as the space-time they have previously experienced is gradually distorted by the introduction of this significant potential. In a sense space-time is the ecosystem of stakeholders and importantly their relationships, ideas and priorities[5].

Second, as we undertake the execution of the project, converting "potential energy" into "kinetic energy" and ultimately into the resultant project "mass" we draw into the local project setting mass from outside of the local region. Remember, in the large complex project setting mass represents the tangible form of some work (kinetic energy) times a conversion factor. Think of the formation of the planets as they progressively drew other nearby masses together in their formation. As this transformation process is happening these logistical flows are themselves distorting local regions of space-time, sometimes at great distance. This transformational period for the project creates a growing and unpredictable distortion in space time as more and more flows enter the project, sometimes interfering with each other or even transforming one another[6]. The interaction between the project and its local space-time is not deterministic but rather emergent as are the distortions in space-time that the project creates.

Finally, the project is complete or perhaps said another way it is now stable with a well-defined and steady (distortional) relationship with its local space-time. It may be perturbed at a later time but that is not of interest here. While the project has now reached a stable phase the transformation phase has had far reaching effects. Relationships with nearby

[5] I have referred to this as the project's ecosystem and also as the stakeholder ecosystem in other contexts. My current thinking suggests that this broader space-time concept are these and more.
[6] Flows in Large Complex Projects; National Academy of Construction Executive Insight; https://www.naocon.org/insights/

stakeholders have been reframed (space-time has been distorted), with the potential of longer lasting perturbations in this project-stakeholder system. Logistical chains have been significantly modified often with very different pre and post-project trajectories. This may impact subsequent project transformations even at a distance.

Our large project is transformed in an expanding dynamic system that is changing overall even as we seek to create a local region of stability.

Let's look at our project's space-time setting a little closer. It is not just distorted by the introduction of the relativistic energy of the project but it is itself turbulent, akin to what quantum mechanics might suggest. New issues pop in and out of existence and the extent to which they define or modify the local setting, local region of space-time, is uncertain. Space-time is endowed with properties. It is defined by its relationship to different objects. Space-time itself is emergent.

The project setting and its interaction with space-time both locally and at a distance behaves very much as an open system. As a result our project has a relatively open scope for possibilities, certainly not what classical project management theory with its closed systems view would suggest. Our large complex project, like all open systems, tends toward differentiation, growth in complexity and networking with other systems, such as the supply chains which feed it but also many more.

Black Holes

Let's turn now to a characteristic predicted by the General Theory of Relativity, black holes. In physics these represent regions in space-time where extreme densities so distort space-time that no energy or information can escape. Their gravity is so strong that they effectively create a hole in normal space-time. In large projects we experience two different types of black holes. The first is at the foundational center of our project and the second is at a distance, containing a great potential for catastrophic action that while remote should not be ignored.

Let's look at the first type, those present in the foundational cores of our project universe. In physics, a black hole is a region of space-time where gravity prevents anything including light from escaping. In the universe of projects the analogous region is one which prevents a strongly founded project from being initiated. These black holes may manifest themselves as weak or absent project definition processes, with well-defined stage gates that ensure a well-founded project. Alternately, they may be masked by the perception of a well-founded project only to discover later on that the fundamental assumptions underpinning the project suffer from optimism bias or underestimating the true nature of risk[7].

[7] Foundations for Success; National Academy of Construction Executive Insight; https://www.naocon.org/insights/

The second type of black holes becomes important when we consider the project universe equivalent of gravitational waves.

Before moving onto gravitational waves a final thought on black holes is in order. Quantum field theory in the curved space-time which is characteristic of black holes says that the horizon of the black hole has entropy[8]. In our project universe this may represent a possible means to detect and assess these black holes remembering that the entropy is related to its area so the smaller black holes at the center of our project foundations may be harder to detect.

Gravitational Waves of Large Complex Projects

In relativistic physics, gravitational waves are ripples in space-time, events that literally cause the displacement of space-time itself. In the simplest terms they result from asymmetrical energetic events. The amplitude of the resultant waves is inversely proportional to their distance from our system (as opposed to energy dissipation which is inversely proportional to the square of distance). Amplitude is also proportional to the energy of the initiating event. One source of these gravitational waves are black holes that interact with or combine with other black holes in some energetic way.

In our project system, large, proximate black holes, regions of potentially catastrophic risk, are capable of suddenly changing the space-time of our project system. The nature of the sudden realization of this potential disruptive event and what causes its sudden emergence remain a subject for further consideration. But what is known is that the emergence of these events and the resultant amplitude they create in space-time can have catastrophic effects on our project. In our project system we refer to these sudden unexpected events with catastrophic consequences as Black Swans. There may be more to discover about the impacts of the project equivalent of gravitational waves by recognizing that they originate from four different types of originating events. Perhaps Black Swans have some relatives not yet recognized.

Time Dilation

One of the predictions of General Relativity relates to the passage of time as experienced by two observers. In physics, if one observer is moving very fast, time takes longer to pass as compared to what the other outside observer sees. This is called time dilation. This same time dilation occurs in the presence of strong gravitational fields such as those caused by large masses in space-time.

[8] Hawkings radiation

Analogously, in large complex projects, project time passes more slowly than it would for an outside observer (real world time). Now, this is not as if all project clocks run slow but rather the larger and more complex a project the harder and slower it is to make progress. The mass of the project and the strength of its distortion on local space-time create a degree of difficulty not experienced with smaller projects.

Conversion of Energy to Mass

Mass represented the conversion of relativistic energy such that energy (E) times a conversion factor ($1/c^2$ in the case of special relativity) was equal to the mass resulting from the conversion of energy to a more tangible form.

In General Relativity the more familiar form of $E=mc^2$ is replaced with $E=\lambda mc^2$, where $\lambda = 1/(\sqrt{(1-v^2/c^2)}$ [9]. At rest, the rest energy for a given mass is mc^2. As we accelerate this mass the kinetic energy of an object moving at relativistic speeds is equal to $(\lambda - 1)\, mc^2$. As we accelerate a given mass to higher energy levels significantly more and more energy is required and no mass can ever be accelerated to the speed of light.

In the universe of projects as we seek to increase the resultant outputs (mass) the increase in human activity (energy) is non-linear, growing either with total project size or accelerated mass deployment (shorter schedule). Assuming a relationship similar to what we see in relativistic physics, increasing the "velocity" of the project from 89 to 90% of a theoretical maximum would require 4.6% more energy while increasing it from 93 to 94% would require 7.7% more energy. Project acceleration faces the same energy challenges as mass acceleration.

So What Does This Mean for Large Projects?

Large complex projects are not well served by classical project management theory. Classical theory fails at scale much in the way Newtonian physics was replaced by relativistic physics at scale. This paper examines several components of relativistic physics as an analogy for what we observe in the universe of large complex projects. There is much we can learn and the General Theory of Relativity provides a framework for rethinking our assumptions and approach to large complex projects.

[9] √square root

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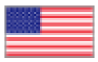

Bob Prieto is a senior executive effective in shaping and executing business strategy and a recognized leader within the infrastructure, engineering and construction industries. Currently Bob heads his own management consulting practice, Strategic Program Management LLC. He previously served as a senior vice president of Fluor, one of the largest engineering and construction companies in the world. He focuses on the development and delivery of large, complex projects worldwide and consults with owners across all market sectors in the development of programmatic delivery strategies. He is author of nine books including “Strategic Program Management”, “The Giga Factor: Program Management in the Engineering and Construction Industry”, “Application of Life Cycle Analysis in the Capital Assets Industry”, “Capital Efficiency: Pull All the Levers” and, most recently, “Theory of Management of Large Complex Projects” published by the Construction Management Association of America (CMAA) as well as over 700 other papers and presentations.

Bob is an Independent Member of the Shareholder Committee of Mott MacDonald. He is a member of the ASCE Industry Leaders Council, National Academy of Construction, a Fellow of the Construction Management Association of America and member of several university departmental and campus advisory boards. Bob served until 2006 as a U.S. presidential appointee to the Asia Pacific Economic Cooperation (APEC) Business Advisory Council (ABAC), working with U.S. and Asia-Pacific business leaders to shape the framework for trade and economic growth. He had previously served as both as Chairman of the Engineering and Construction Governors of the World Economic Forum and co-chair of the infrastructure task force formed after September 11th by the New York City Chamber of Commerce. Previously, he served as Chairman at Parsons Brinckerhoff (PB) and a non-executive director of Cardno (ASX)

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