

Utilizing Team Productivity Models in the Selection of Space Exploration Teams

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ABSTRACT

The term “productivity” all too often has become a buzz-word, ultimately diminishing its perceived importance. However, productivity is the major concern of any team, and therefore must be defined to gain an appropriate understanding of how a system is actually working. Here, productivity means the level of contribution to the throughput of a system such as defined in the Theory of Constraints. In the field of space exploration, the throughput is the number of milestones of the mission accomplished as well as the potential survival during extreme events (due to failures or other unplanned events).

For a time tasks were accomplished by expert individuals (e.g., an astronaut), but recently team structures have become the norm. It is clear that with increased mission complexity, “no single entity can have complete knowledge of or the abilities to handle all matters” [10]. Understanding now that teamwork is important, beneficial, and becoming the standard, a team profile must be developed. This profile will include team member selecting factors (e.g., general intelligence), team organization, and team management.

This paper outlines our initial research about the tools used to analyze team productivity to be applied specifically to a space exploration mission. A simple system dynamics model is developed representing the team profile and their activities. This model will later be judged by a panel of experts to be a realistic tool for team selection.

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INTRODUCTION

Productivity is the major concern of any organization. This is however to say, that often the term “productivity” becomes a buzz-word and must be defined to gain an appropriate understanding of how a system is actually working. Here, productivity means the level of contribution to the throughput of a system such as defined in the Theory of Constraints. In the field of space exploration, the throughput is the number of milestones of the mission accomplished as well as the potential survival during extreme events (due to failures or other unplanned events). Of concern is how to maximize productivity of space exploration teams.

In order to explore maximizing these teams' productivity in the whole, one must look to its constituent parts. For a time these parts consisted of expert individuals (e.g. a material scientist), but recently team structures have become the norm. “The production of scientific knowledge has evolved from a process of inquiry largely based on the activities of individual scientists to one grounded in the collaborative efforts of

specialized research teams” [13]. Shifting the paradigm of production from the individual to the team is not peculiar to research. “Research on teamwork in organizations has typically found positive outcomes for employees, such as high productivity, improved satisfaction, and a greater feeling of influence over their work” [13]. Son and Rojas (2011) give a great description of why teams are not only used, but why they become more and more necessary “as construction projects get larger and more complex, it has become clear that no single entity can have complete knowledge of or the abilities to handle all matters” [10]. This arguments for teams take on a similar form to the argument for capitalism (where the entire world is the team) presented in *I, Pencil*

I, Pencil, simple though I appear to be, merit your wonder and awe, a claim I shall attempt to prove. In fact, if you can understand me-no, that's too much to ask of anyone-if you can become aware of the miraculousness which I symbolize, you can help save the freedom mankind is so unhappily losing. I have a profound lesson to teach. And I can teach this lesson better than can an automobile or an airplane or a mechanical dishwasher because-well, because I am seemingly so simple. Simple? Yet, not a single person on the face of this earth knows how to make me (original emphasis) [16].

The processes required to make something as ordinary as a pencil are many and varied, and no individual processes the knowledge or ability to accomplish them all. This is also the case with the increased mission complexities for space exploration. "Organizations are increasingly becoming dynamic and unstable. This evolution has given rise to greater reliance on teams and increased complexity in terms of team composition, skills required, and degree of risk involved" [1]. Teams provide synergetic benefits as well, in other words "understanding the preconditions and underlying mechanisms of process gains in teams enables managers to trigger performance levels of teams that exceed what can be expected based on the individual team members' capabilities alone" [5]. Understanding now that teamwork is important, beneficial, and becoming the standard, a team profile can begin to be developed.

INVESTIGATIVE TOOLS

Regression Analysis

The question that is posed here is what selecting factors lead to a team's success. We found through our survey that researchers have utilized many tools in their efforts to answer this question, one of which is regression analysis. At its core, statistical regression analysis is a "formal expression of a statistical relation" [6]. In previous investigations, productivity takes the place of the response variable which has a tendency to vary in a systematic way with certain predictor variables. Once an appropriate regression model is formed, the predictor variables will represent the selecting factors that may be utilized to improve team productivity. These may include number of team members, or more qualitative measures such as level of degree earned by team members. The surveyed research used various regression tools to create models for analysis for descriptive, control, and prediction purposes. Salas, Rhodenizer, and Bowers (2000) conducted a survey to establish a design and method for "Crew Resource Management Training" [9 10]. This survey found several factors related to teams and teamwork and increased crew productivity through meta-analysis including: cohesiveness and commitment to the task (Mullen

& Cooper 1994); inclusion of automation (Bowers, Deaton, Oser, Prince & Kolb 1995); communication structure within cockpits (Kanki & Palmer 1993); situational awareness, metacognition, shared mental models, and efficient resource management (Orasanu 1993) [9 10]. Simulating the extreme environments of space, researchers look to Antarctic expeditions. Analyzing how individuals adapt to these extreme environments, Gunderson (1996) found through regression analysis that being the oldest child, having multiple hobbies, disliking model building, being paranoid, being motivated, confident, and wanting affection among other factors are highly correlated with overall effectiveness [4]. Looking at the cohesion within these isolated groups, Vallacher, Seymour & Gunderson (1977) found "cohesiveness indices based upon positive intermember attraction were negatively correlated with incidence of emotional symptomatology within station groups" [17]. Schmidt, Wood, & Lugg (2004) collected data from Antarctic research stations from 1996 to 2000 finding that "perceived leadership effectiveness was significantly related to team climate" [11]. Combining the findings of these studies, a model begins to emerge as to what the profile of a productive team contains.

Regression models produced are sought to be parsimonious and are thoroughly validated and verified with additional data not used in its original formulation. There is however, a limit to the power and capabilities of such models. "In general, accurate methods such as regression models [15,36] may produce results that have reduced informative value [27]" [2]. Although a regression model can give estimates of the response based on different predictor levels, these predictor levels must be within the scope or range of the predictor used in the model formulation. Thus if one wanted to look at the response for a team comprised of 20 members, a regression model created from data containing team sizes up to 10 members cannot be used. Also, "the resulting model is not necessarily intuitive or explanatory, especially when the attributes used for the prediction are highly correlated or when there are violations of the underlying assumptions" [2]. Another major shortcoming of these models is in the fact that correlation does not mean causation. "Regression analysis by itself provides no information about causal patterns" [6]. One also cannot represent behavior well in these models, or truly explore system optimization.

Mixed Integer Programming

Optimization of a system often takes the form of maximizing or minimizing a quantity such as cost. One paper surveyed used this approach in its investigation. In an attempt to optimize workforce planning by minimizing costs within a fictitious "job shop", Wirojanagud, Gel, Fowler, & Cardy (2007) created a Mixed Integer Programming (MIP) Model.