2007-04-01

Acquisition Community Team Dynamics: The Tuckman Model vs. the DAU Model

Pamela Knight

NPS-AM-07-009

EXCERPT FROM THE

PROCEEDINGS

OF THE

FOURTH ANNUAL ACQUISITION RESEARCH SYMPOSIUM WEDNESDAY SESSIONS

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Published: 30 April 2007

by

Pamela J. Knight, PhD, Defense Acquisition University

4th Annual Acquisition Research Symposium of the Naval Postgraduate School:

Acquisition Research: Creating Synergy for Informed Change

May 16-17, 2007

Prepared for: Naval Postgraduate School, Monterey, California 93943

Acquisition Research program
GRADUATE SCHOOL OF BUSINESS & PUBLIC POLICY
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The research presented at the symposium was supported by the Acquisition Chair of the Graduate School of Business & Public Policy at the Naval Postgraduate School.

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Acquisition Community Team Dynamics: The Tuckman Model vs. the DAU Model

Presenter: Pamela Knight is currently a Professor of Systems Engineering and Software Acquisition Management with the DoD Defense Acquisition University (DAU). She has accumulated 25 years of professional experience in the fields of physics, engineering, test, systems engineering, software acquisition management, information technology, and a broad spectrum of activities in program management. Her technical expertise includes neural network applications; data storage and retrieval; information assurance; information operations; data sharing and collaboration; Intelligence Analysis; radar, laser radar, infra-red sensor analysis; ballistic missile interceptor evaluation; battle management/command, control, communications, computers and intelligence (BM/C4I) and signal processing.

Prior to her position with DAU, Dr. Knight spent 12 years at the US Army Space and Missile Defense Command (USASMDC). Preceding her employment with USASMDC, she gained experience supporting the missile defense programs in the industrial arena. Dr. Knight also served as a technical Intelligence Analyst for the Army Foreign Science and Technology Center (now called the National Ground Intelligence Center) from 1980 to 1983. Pamela earned a Bachelor's degree in Physics from the University of Virginia and a Master's degree and PhD in engineering from the University of Alabama in Huntsville. She has received numerous awards and recognition during her career.

Pamela J. Knight, PhD
Professor, Systems Engineering
Defense Acquisition University
6767 Old Madison Pike, Bldg 7
Huntsville, AL 35806
Phone: (256) 722-1071
Fax: 256-722-1003
E-mail: Pamela.knight@dau.mil
Website: www.teamresearch.org

Abstract

The Tuckman (1965) four-stage sequential model of team development (Forming, Storming, Norming, and Performing, or FSNP) represents today's most widely used model. However, the Tuckman model is a conceptual statement that was suggested by the data and has not been empirically validated (Tuckman, 1965). Hadyn, Teare, Scheuing and Armistead (1997, p. 118) state that, "despite increasing interest in teamwork, much of the literature on the subject is inconclusive and often derived from anecdote rather than primary research."

The goal of this research was to develop empirical evidence to determine whether or not the Tuckman model or some variant thereof provides an appropriate model to explain the development of small, short-duration technical teams within the Acquisition Community.

The results showed, to a 95% confidence level, that only about 2% of 321 teams studies followed the Tuckman model (FSNP). However a modified model, called the DAU Model (FNP—Tuckman model sans Storming), was experienced by 229 of the 321 teams (77%). This discrete three-stage model, along with a redefined Storming function that takes

place throughout the teams' duration, constitutes a strong model of team dynamics for the studied Acquisition population.

This research demonstrates that not only do technical teams generally follow the DAU model, but also that there is a strong correlation between teams producing above-average products and teams following this model. The results of this research strongly suggest the possibility that the productivity of a technical team may be significantly improved by guiding its development through a well-defined process.

Background

How to build effective teams is one of the most important management issues of the day. Significant effort is being expended to gain a better understanding of how highly successful teams develop in hopes that methodologies to enhance team productivity can be produced that will accelerate the movement of high-quality products to the marketplace (Osterman, 1994). In Quality Circles, Concurrent Engineering, and many other management innovations, the team is the organizational unit to which creative control is being delegated. As a result, there is a great need to better understand the development of technical teams.

The culture of many of today's businesses places as much emphasis on a person's ability to work together effectively in a team environment as on technical skills (Tarricone, 2002). Osterman (1994) found that teams are being used extensively by organizations that need to get products to market faster. Some industries have reported that teaming brings advantages such as increased productivity and decreased absenteeism (Beyerlein, 2001). According to Beyerlein, the use of task-oriented teams within organizations has spread across many industries, nonprofits, and national boundaries in the last decade. Kinlaw (1991) found that teamwork is the main driver for continuous improvement and increased competitiveness. According to Marks (2001), the advantage of teamwork is that people working together can often achieve something beyond the capabilities of individuals working alone. Furthermore, Marks points out that success is not only a function of team members' talents and the available resources but also of the processes team members use to interact with each other. Research on the development and functioning of teams is needed to enable organizations to retool human resource systems so that managers can better select, train, develop, and reward personnel for effective teamwork (Marks, 2001). To remain competitive, it is important for organizations to understand how to create and maintain teams that are highly effective in today's globally competitive environment (Yancey, 1998).

Introduction—the Importance of Teams to Defense Acquisition and the Defense Acquisition University (DAU) Connection

Short-duration, small technical teams represent a significant proportion of the team activities within the Department of Defense (DoD) acquisition community and corporate organizations. These teams come together, focus on the task at hand, produce whatever products are required, communicate their results, and then disband as easily and quickly as they were formed (Canadian Business, 2001). Wherever highly specialized knowledge spanning multiple disciplines is required, the technical team enjoys widespread use. Some examples are as follows:

- Multi-disciplinary Product Integration Teams

- Tiger Teams (narrow focus, single issue)
- Proposal Teams
- Design Teams
- Educational/Training Teams
- Problem Resolution Teams
- Product Development Teams
- Marketing/Sales Teams

In today's environment, short-duration, small technical teams drive an enormous quantity of critically important decisions within a broad range of organizations in all sectors of the US economy. The DoD acquisition community is one such sector that makes extensive use of technical teams. Thus, understanding how these teams develop is of critical importance to the DoD Acquisition Community.

DoD acquisition professionals are those in the government who are responsible for acquiring weapon systems for the Department of Defense. Their collective decisions, made primarily by technical teams, move hundreds of billions of dollars per year, influence the outcome of international conflicts, and determine the effectiveness of the US military. To perform its mission, the acquisition community employs thousands of technical teams to develop the information necessary to make critical decisions and to integrate the development and production of very large, costly, and complex weapon systems. The Integrated Product Teams (IPTs), which has been organic to both industry and DoD acquisition for many years, is a good example of a technical team. The IPT, along with all of the short-duration, small sub-teams it spawns is increasingly being hailed as the preferred way to manage large-scale acquisitions (Weinstock, 2002, p. 1). *DoD Directive 5000.1* requires that the, "Acquisition Community implement the concept of Integrated Product and Process Development (IPPD) utilizing IPTs as extensively as possible" (DAU, 2004, October 17, p. 113).

DoD technical teams are often multi-disciplinary and could include scientists and engineers as well as management, contracts, budget, security, quality, survivability, and logistics personnel from both the developer and the user organizations (DAU, 2004, October 17). DoD teams often include contractor personnel as well as government employees. DoD acquisition activity centers on extremely large and complex systems that often push the state-of-the-art in many fields simultaneously. The acquisition workforce numbers approximately 133,000 people, including both military and civilians. It is vital to the success of integrated military systems that all the stakeholders work together as efficiently and productively as possible (Weinstock, 2002, August 15).

Because countless lives, billions of dollars and the national interest are at stake, the US Congress required the Department of Defense to take action to promote high levels of professionalism and competency within its acquisition workforce. One action taken by the DoD was to establish a process of training and certification for individuals in the acquisition workforce. The Defense Acquisition University (DAU) was established to implement this training. This process, called the Acquisition Certification Program, was designed to ensure that an employee meets the professional standards (education, training and experience) established for acquisition career positions at three separate levels of decision-making responsibility; in addition, promotion opportunities are tied to these certification levels.

The DAU charter is to provide training to the DoD workforce that sets the direction for all DoD acquisitions. Due to the emphasis the DoD places on teamwork, many of the DAU classes are conducted utilizing student teams to generate typical DoD acquisition products. Examples of classes that make use of teams are: Systems Engineering, Program Management, Software Acquisition Management, and Information Technology Acquisition Management. The DAU's use of student teams is consistent with many conventional universities who are also requiring teaming activities in their courses. These student teams are used to enable the generation of more complex products and to prepare the students for the inevitable teaming requirement in the workforce. It was these DAU teams that were studied by this research.

The Tuckman Model

In 1965, Tuckman examined 50 empirical research efforts to arrive at his own group dynamics model. Tuckman (1965) concluded that groups develop through a sequence of four discrete stages: the first stage, Forming, is the initial group coming together; the second stage, Storming, involves conflict among the group members; the third stage, Norming, is when the group actually begins to find value in working together and establishes processes that enable the group to function; and the fourth stage, Performing, represents the time when the group is working together smoothly and is able to share ideas and accomplish goals. However, Tuckman (1965) warned researchers that the application of this model to generic team settings may be inappropriate since the majority of his data came from the population of therapy groups and human relations training groups. Note that the types of groups from which the Tuckman model was derived have almost nothing in common with the technical groups supporting DoD acquisition.

Many government organizations, contractors, and management consultants appear to be working under the assumption that a team's productivity can be significantly improved by optimally guiding the interaction of the team's members through the Tuckman model's sequence of stages (Glacel & Robert, 1995). Buchanan and Huczynski (1997) found the Tuckman model to be the preferred model of team development for all types of teams. It is widely believed in both industry and government that a leadership knowledgeable in how to apply Tuckman's theory of team dynamics can markedly enhance teaming performance. Top-tier consulting firms are teaching or offering training services based at least partially upon the assumption that the Tuckman model applies generically to most teaming arrangements (Glacel & Robert, 1995; Smith, 2005). Many DoD organizations have received such training. Glacel and Robert (1995) state that the Tuckman model can be used to facilitate any team-development process. They present the efficacy of the Tuckman model as a general model that applies to all teams. They state with certainty: "In the development of any team, certain stages of behavior [Tuckman stages model] take place which impact how well the individuals and the team accomplish their task" (Glacel & Robert, 1995, p. 97).

Notwithstanding its widespread use, Tuckman did not empirically validate his model (Tuckman, 1977). The government and industry managers are, thus, teaching and implementing a team-development model that has never be validated for any type of team, including the technical teams that are predominant within the DoD acquisition process. Large sums of money and critical outcomes may be influenced by the wide use of the Tuckman Theory, which was primarily developed through an analysis of data describing the development of therapy groups and human relations training groups during the mid-1960's.

Tuckman himself warned the group development community that his stage model had never been empirically validated and recommended caution in applying it to other settings (Tuckman, 1965). Subsequent to the original work, Tuckman and Jensen (1977) reviewed another 22 studies in an effort to determine if anyone had validated the Tuckman model. In 1977, the only new research that had attempted to validate the model was Runkel (1971). Runkel partially supported the Tuckman model; however, Tuckman and Jensen (1977) felt that the results were not necessarily reliable due to the researcher's methodology.

Even if the Tuckman model of group development was valid for therapy groups and human relations training groups, there is no reason to assume that it would be applicable to groups in other settings. Do the members of a missile design team interact in the same way as the members of a psychiatric therapy group? Perhaps, but independent empirical validation is needed before giving credibility to such an assumption.

Data Collection

The objective of this research was to establish and execute a methodology that would enable an objective, rigorous analysis of a large number of teams in order to determine whether these teams were following the four-stage Tuckman model, or some variant thereof. For this research, the team members were drawn from the population of students attending the DoD Defense Acquisition University (DAU) courses. The DAU employs technical acquisition teams in most of its classroom courses to emulate the activities that acquisition professionals face in their everyday work experiences. The classroom courses are used to provide hands-on experiential learning. Experiential learning at DAU requires that students work in teams in which they gain professional experience solving real-world problems that closely mirror both the teams and the tasks that they encounter in their workplace environment.

These DAU teams could technically be classified as academic teams because they take place in a classroom where an instructor assigns the team project. However, functionally it could be argued that they are more like work teams because the assigned tasks emulate real-world problems that the team members are typically asked to solve in a work-team environment within their own organizations. The DAU teams are brought together to learn and to practice working real-world problems. If the DAU team members are role playing, then the role they are playing is themselves at work.

As is the case with work teams, the researcher had no control over the team tasks. Individual team projects, which take from one to twenty hours of team interaction to complete, are relevant to the tasks team members accomplish within their own organizations. The team projects are selected by the course instructor. DAU teams normally contain 4 to 8 team members.

All team exercises within the DAU require products to be developed and delivered by the end of the exercise. The products delivered in the class are similar to products delivered in the DoD acquisition environment. For example, a Systems Engineering class is required to perform a Requirements Analysis Task within the class team. These are the people who perform Requirements Analysis Tasks within the Acquisition Workforce.

The instructor graded each team's product quality. It can be assumed that students are generally motivated to develop the best products they are capable of producing within

their teams because the quality of their work is openly graded. Furthermore, passing DAU courses is dependent upon the quality of their teamwork as well as the quality of their team products (in addition to their final exam grades). Since passing a DAU course earns a certain level of certification within the Acquisition Corps, and since certification levels are tied to career advancement opportunities (DoD, 2005, January 12), DAU students generally take their teaming activities seriously and are motivated to work well together.

For this research, the Diane Miller (1997) Group Process Questionnaire (GPQ) was utilized to collect data to determine if events defining the Tuckman stages took place within the DAU technical acquisition teams being observed. If the instrument determines that a team member observed "Tuckman events" taking place within the team, then data is gathered to define when these events occurred and how long they lasted. Dr. Miller involved team dynamics subject-matter experts to generate her GPQ and then performed a validation study to eliminate questions that did not reflect the team dynamics models of interest. The DAU Research Report entitled "Small, Short Duration Technical Team Dynamics" provides more details about how this instrument was selected (Knight, 2006). Miller's questionnaire contains 15 questions that are reflective of the Tuckman model (Miller, 1997). Figure 1 provides a list of the 15 Tuckman questions included in the GPQ.

The GPQ required 10-20 minutes to complete. Each of the 15 Tuckman questions asks the individual to determine if an event (correlated with one of Tuckman's four stages) happened during a specific teaming exercise and if so, when it happened and how long it lasted. The point at which the event occurred and its duration were recorded on a timeline scaled from 1-50. If the event was a singular event that occurred at one instant of time only, then the person would click a single unit (box) on the timeline. If it occurred various times with various durations, the person would indicate each occurrence and its duration by clicking a series of contiguous boxes. A sample timeline is shown in Figure 2.

Stage	Question	GPQ Question
F1	14	The team attempted to discover what was to be accomplished
F2	24	Individuals tried to determine what was to be accomplished
F3	31	The team tried to determine the parameters of the task
S1	1	There was conflict between group members
S2	5	Individuals demonstrated resistance towards the demands of the task
S3	16	The group was experiencing some friction
S4	20	Group members became hostile towards one another
N1	11	Individuals identified with the group
N2	23	Group norms were developed
N3	26	The team felt like it had become a functioning unit
N4	30	Group cohesion had developed
P1	3	Solutions were found which solved the problem
P2	6	A unified group approach was applied to the task
P3	21	Constructive attempts were made to resolve project issues
P4	22	Problem solving was a key concern

F=Forming S=Storming N=Norming P=Performing

Figure 1. Tuckman Questions in the Group Process Questionnaire

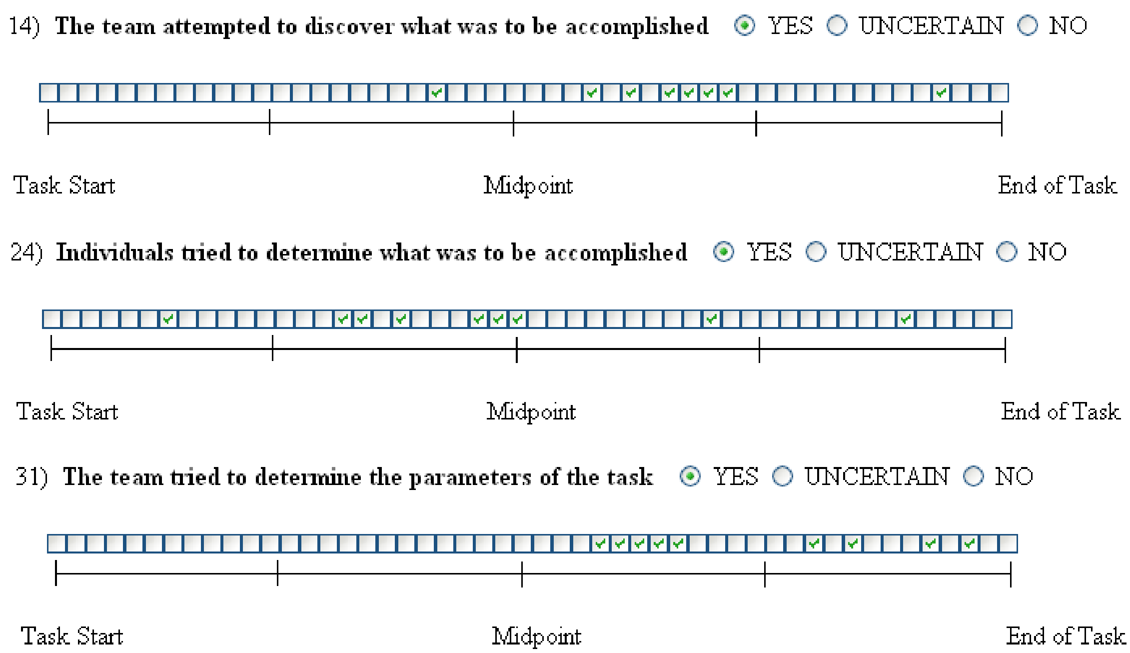

Figure 2. Sample Question Timeline

Originally, 368 teams were surveyed with a response rate of 90%. The research population consisted of 321 teams and 1448 individuals. The average team size was 4 to 5 members but ranged from 2 to 8 members. The durations of these team projects ranged from one hour to two-and–a-half days. This population contained 68% males, 30% females and 2% who did not indicate their gender. Because the more technical professions (particularly engineering) are predominately male, this lopsided gender breakdown is normal and expected within the DAU. The DAU students studied in this research project represent a typical set of DAU students. They are generally well-educated career professionals working in a predominately technical environment. Figure 3 shows the percent of team members versus highest degree attained. Note that 88% have at least a college degree (BS/BA) and almost 40% have completed graduate degrees. These team members are generally aware and bright and should have no trouble understanding the questions asked by the questionnaire or being able to relate those questions to the events they witness in their teams.

High School	BS/BA	MS/MBA	PhD Doctorate
12%	50%	36%	2%

Figure 3. DAU Survey Population Education Levels

The courses offered at DAU are typically not taken by inexperienced acquisition employees. These are not entry-level courses, but rather are aimed at midlevel and senior professionals who are actively trying to advance their careers. This group of career-ladder climbers tends to have more drive and energy and is a little more intellectually aggressive than the typical acquisition employee. The DAU teams in the research population are, on

the average, composed of midlevel (11-years experience) professionals on the way up in their organizations. They have been working in product-oriented technical teams in a professional capacity for over 7 years and have previously worked in teams with one or two of their current teammates. Incredibly enough, over 71% of them have had some training in the techniques of productive teaming. Bottom line: These teams are highly experienced, motivated, and well prepared to work efficiently together to produce whatever products are demanded by their various class exercises.

The DAU instructor evaluated the quality of each team's products. Figure 4 shows how those evaluations were distributed over the 321 teams. The instructors judged there to be 145 above-average, 151 average and 25 below-average products.

	Above Average	**Average**	**Below Average**
Number	145	151	25
Percent	45%	47%	8%

Figure 4. Instructor Evaluations of Team Products for 321 Teams

Analysis Methodology

This research defines a statistically valid teaming experience as one that can be proven to a 95% level of confidence to be derived from information measured by the GPQ that has been certified to be both accurate and statistically meaningful. That is, each team's qualitative and quantitative experience of a given sequence of Tuckman events (as measured by the GPQ) must be shown to be very unlikely ($P \leq 0.05$) to have occurred as a result of random fluctuations in the data (noise).

An assessment of the ability of the data collection methodology to fully support the goals of this research project was undertaken. A statistical analysis of the time-of-occurrence data generated independently by each DAU team member clearly demonstrated that the data is able to support statistically rigorous results and conclusions about whether or not DAU teams followed the Tuckman linear sequential model. Data-quality standards were enforced to ensure that the research database contained a minimum of noise and disinformation. Also, it was statistically shown that team members were able to clearly assess the behavior within their teams relative to the Tuckman model event descriptions described by the GPQ. Finally, it was shown that the time-of-occurrence data upon which the results of this research are based contain a high enough signal-to-noise ratio to ensure that derived results can be scientifically credible. Appendices N and M in the DAU research report derive the details supporting these conclusions (Knight, 2006).

To show that each team's experience of a given sequence of Tuckman events was very unlikely ($P \leq 0.05$) to have occurred as a result of random fluctuations in the data, an analysis of the sequences defined by the answers to the questionnaire was undertaken. This methodology is called Sequence Analysis. The GPQ contains 3 Forming questions, 4 Storming questions, 4 Norming questions, and 4 Performing questions. A sample showing one quarter of the sequence analysis algorithm is shown in Figure 5 below. Here we see the 3 Forming questions (F1, F2, and F3) being analyzed relative to the first Storming question (S1) and all of the Norming and Performing questions. The point is to determine the order in

which the four Tuckman stages (F, S, N, and P) occur as given by the timeline data associated with each question. The timing sequence defining the Tuckman model is F<S<N<P (the time when Forming occurs is earlier than the time when Storming occurs is earlier than the time when Norming occurs is earlier than the time when Performing occurs). Similarly, another three of these tables are used for Storming questions 2, 3 and 4. Possible responses are 1 if the sequence indicated by each cell is followed and a 0 if it is not. For example, in the data upon which this sample is based, the sequence F1<S1<N1<P1 did occur. Thus, a 1 is placed in the appropriate cell (second column, fourth row). Likewise, since our data did **not** support the sequence F2<S1<N1<P2, a zero is placed in the third column, fifth row. Each of these 4 tables could produce as many as 63 ones for a total of 252 total points if the Tuckman model is followed 100% of the time by that individual or team. These scores were then scaled to be between 0 if the Tuckman model is not followed at all and 100 if the Tuckman model is followed for all questions.

	F1 <	**F2 <**	**F3 <**
S1<	1	1	1
N1<	1	1	1
P1	**1**	1	1
P2	0	**0**	1
P3	1	1	1
P4	1	1	1
N2<	1	1	1
P1	1	1	1
P2	1	1	1
P3	1	1	1
P4	1	1	0
N3<	1	1	1
P1	1	1	1
P2	0	1	1
P3	1	1	1
P4	1	1	1
N4<	1	1	0
P1	1	0	1
P2	1	1	1
P3	1	1	1
P4	1	1	0
	19	19	18

Figure 5. One Quarter of Sequence Analysis Logical Algorithm (Tuckman Filter)

Another factor that must be considered to determine if the team is following the Tuckman model is how to combine individual data into team data. One approach would be to determine a team position on each Tuckman question and then run this team data through the Tuckman sequence-analysis model. The other approach is to run each individual's data through the Tuckman precedence model and then combine the Tuckman scores for individuals to come up with a team score. **The latter method was chosen for this research.** The reason for this choice is that the alternative requires good data to be

disregarded without good reason for doing so other than to simplify the calculations. If the first approach is selected, the minority opinion of the existence of an interpretative and subjective event is thrown out.

Once a Tuckman score is determined between 0-100, the significance of the score must be determined. A Monte Carlo simulation was used to generate a reference distribution of Tuckman scores. A large number (102,000) of questionnaires were filled out randomly—i.e., randomly answering “YES,” “NO” or “UNCERTAIN” to each of the 15 Tuckman questions and then producing random times-of-occurrence for each “YES” answer. A Tuckman score was calculated for each of the 102,000 random teams. A reference distribution was generated for these FSNP scores by sorting the 102,000 random FSNP scores into 100 bins. For example, all the FSNP scores between 15.5 and 16.499 were counted, and that number was put into bin 16. Because accuracy improves with the number of samples generated, the number of samples used (102,000) simply reflects the practical limits of the available computing resources.

Next, integrating over the distribution produced a cumulative probability curve. This probability curve was then used to generate a numerical level of confidence that a given score was not produced by random data. Obviously, very low FSNP scores requiring little specific organization of the input values are more easily produced by random inputs; yet, very high FSNP scores (requiring all F times to be less than all S times, etc.,) are nearly impossible to produce from 15 random inputs created by a random-number generator. Each FSNP score produced by the DAU data was required to be larger than the random FSNP score associated with a $\square_{SA}$ = 0.05 probability (of being produced by random processes) in order to be declared “significant.” In other words, for an FSNP score generated by a DAU team to be considered statistically significant, it must be large enough such that the probability of that score being produced by random input data is less than 0.05.

Additionally, a sequence of consecutive stages must be composed of discrete, clearly discernable, separate stages or it becomes a mixture of multiple stages—not a sequence of stages as required by the Tuckman model. If stage time-of-occurrences are so overlapped and intermingled in time such that one cannot clearly differentiate consecutive stages, then no bonafide sequence exists. To ensure this requirement for stage discreteness was met, I developed a stage-separation test that, when applied to the data representing the experience of a given team, would tell us (to some statistical level of confidence) whether or not that team’s experience, as measured by the GPQ, constitutes a valid sequence of Tuckman events. In other words, the conditions were precisely defined for sequence validation that determine when two broadly overlapping events belonging to consecutive stages can be said to be separated in time such that they represent two discrete and separate stages to some specified level of statistical confidence.

A parametric analysis was used to assess the sensitivity of research results to the analytical assumptions driving the analysis by varying the thresholds and criteria that numerically represented each assumption. User input parameters specifying constraints imposed upon the analysis were established as user inputs to the analysis engine to allow a parametric analysis of how each input affected both intermediate and final results.

To summarize: An individual’s or team’s FSNP score was counted as being supportive of the Tuckman model only if its value was equal to or greater than the calculated “significance threshold” and if the FSNP sequence was shown (to a 95% probability) to have discrete stages. The significance threshold is an FSNP score calculated within the

Sequence Analysis algorithm associated with a probability of 0.05 that a given FSNP score could have been generated by random inputs. From the random-reference distribution and its associated cumulative probability curve, it was determined that an FSNP score of 0.0976 had a probability of 0.05 of being random. Thus, any score equal to, or greater than, 0.0976 represented a significant score. More detail on random Tuckman score distributions and probability curves can be found in the DAU Research Report entitled “Small, Short Duration Technical Team Dynamics” (Knight, 2006).

In addition to determining if an individual and the team are following the Tuckman model at the 95% level of confidence, this research looked at what other possible forms of the Tuckman model were being followed (i.e., Forming, Norming, Performing OR Forming, Norming, Storming, Performing, etc.). There are 64 possible combinations of alternative sequences of the Tuckman stages. For each individual and for each team, a calculation was performed to determine which of these sequences was being followed. This was then plotted to determine which sequences showed up the most often. The two variants of the Tuckman sequential stages model that were most prevalent were F<N<P and F<N/P (Forming before Norming and Performing). These models were assessed using the same analytical methodology. In the exact same manner described above for creating a Sequence Analysis algorithm $SA_{F<S<N<P}$ that calculates FSNP scores in order to assess the degree to which a statistically valid Tuckman model (F<S<N<P) was experienced by DAU teams, an $SA_{F<N<P}$ algorithm was developed that calculates FNP scores in order to assess the degree to which a statistically valid F<N<P model was experienced by DAU teams. Similarly, an $SA_{F< N/P}$ algorithm was developed that calculates FN/P scores in order to assess the degree to which a statistically valid F<N/P model was experienced by DAU teams. The significance threshold for F<N<P sequences was 4.251, and the significance threshold for F<N/P sequences was 6.511.

Results

The final results are shown in Figure 6. Only 6 teams (2%) out of 321 experienced a statistically valid Tuckman sequence; it is clear that the technical acquisition teams of DAU did not follow the Tuckman model. This outcome was primarily driven by a lack of Storming within the teams. Secondly, Norming and Performing appear to be interspersed in time to such an extent that it is difficult to separate the two.

Tuckman Model - FSNP		
Test	**Teams**	**Individuals**
Raw Time-of-Occurrence	1%	3%
Sequence Analysis	2%	6%
Tuckman Variant - FNP		
Test	**Teams**	**Individuals**
Raw Time-of-Occurrence	49%	26%
Sequence Analysis	71%	44%

Tuckman Variant – F N/P		
Test	**Teams**	**Individuals**
Raw Time-of-Occurrence	71%	46%
Sequence Analysis	90%	70%

Figure 6. Results Summary

There were several attributes of the DAU teams that might possibly be related to the lack of Storming behavior. The first attribute is team size. Typical DAU team sizes were 4 to 8 team members. One might wonder if small teams Storm less than larger teams. Further research would have to be performed to provide a conclusive answer to this question; however, Benfield (2005) also found very little Storming in his data, yet his team sizes were not restricted to such small sizes. In fact, 43% of his teams had more than 11 team members. The second attribute is the short duration of teaming activity. The median DAU team duration was 4 hours, while no team duration was greater than 20 hours. The question here is: Do short-duration teams Storm less than longer-duration teams? To conclusively determine the effect of team duration upon the incidence of Storming, further research is required. However, according to Benfield's (2005) research, 53% of the teams he studied lasted longer than 12 months and also produced very little Storming behavior relative to the other stages.

The third attribute that may have influenced the lack of Storming within DAU teams is team setting. The DAU teams were in an academic setting which, because of the nature of DAU and DAU teams, could be considered somewhere between Tuckman's (1965) *natural* and *laboratory* settings; however, DAU teams are most similar to Tuckman's natural teams. Benfield (2005) studied *natural* teams working in a DoD technical environment and similarly found a low level of Storming relative to the other stages. There is yet another attribute of the DAU academic setting that may have influenced the amount of Storming behavior exhibited. DAU teaming exercises take place in the presence of an instructor and are subsequently graded by this instructor. This is analogous to a natural team when "management" is a part of the team or closely monitors the team. Cooperative professionalism is encouraged while conflict, resistance, and hostility are often discouraged whenever a neutral authority with significant power over the team members is observing the process. In other words, team members may have been exhibiting their best professional behavior rather than the less politically correct behavior they might have exhibited within a group of peers. Certainly, "resistance to the task" would be muted in the presence of the instructor who assigned the task and who was going to grade the task products.

In addition to the lack of Storming found, the distribution of Storming data was more or less uniform across the entire timeline (team duration), as shown in Figure 7.

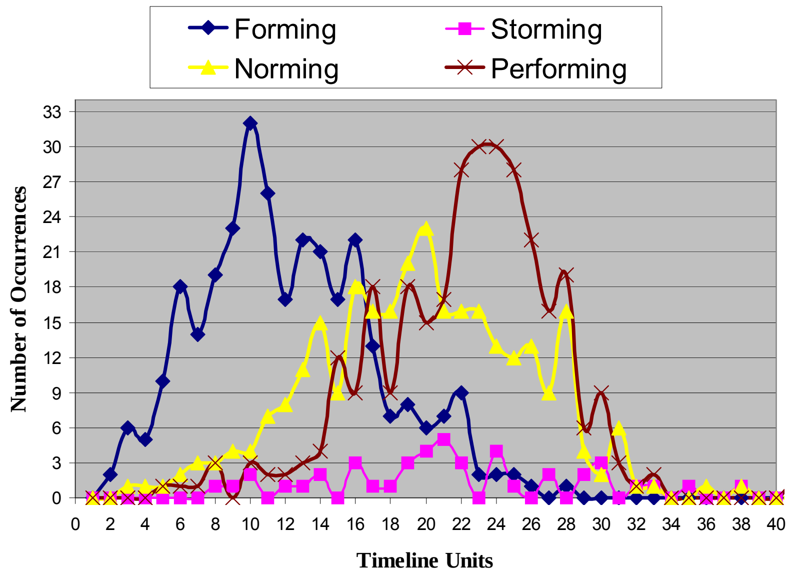

Figure 7. Average Time-of-occurrences for Each Stage for 321 Teams

This characteristic of a constant low level of Storming spread evenly across the entire duration of a team's activity was also observed in Benfield's (2005) data analyzing technical teams. The other three stages generally occurred at a specific location on the timeline, i.e., their distribution exhibited a well-formed peak on the timeline much like that predicted by LaCoursiere (1980). Thus, if the Storming questions were changed to be more sensitive to the vigorous (but cooperative, positive, and professional) competition of ideas that often takes place within a technical team, there may be more of this newly defined Storming (e.g., cooperative brainstorming) but perhaps still no well-defined Storming stage.

To achieve their goals, it is often necessary for technical team members to challenge each other. Although disagreements and divergent points of view were common among DAU teams, they usually were resolved quickly within a cooperative and non-confrontational (minimal friction, resistance, or hostility) atmosphere according to their technical merits. This type of professional challenging may have occurred at any time throughout the teaming process but did not cause many DAU teams to exhibit the Storming stage as defined by the Tuckman model and as represented by the Miller GPQ (i.e., conflict, resistance, hostility and friction). The two Storming questions that described conflict and friction (as in conflicting ideas, and the friction between competing viewpoints) were responsible for Storming behavior being lightly (14%) scattered throughout the DAU data. The Storming questions that focused on resistance to the task and especially the one focused on hostility between team members were not relevant to the observations of the teams being studied.

In summary, a comparison to Benfield's (2005) data suggests that the lack of Storming within the DAU data is not an attribute of team size, duration, or team setting. Thus, it is suspected that the lack of Storming is a natural attribute of technical professionals working under time constraints to produce good-quality products for which they are held collectively responsible. The technical team setting of this research and Benfield's (2005) research is dramatically different in form, purpose and content than the dominant setting (therapy groups) used by Tuckman (1965). It seems reasonable that Storming, as Tuckman

(1965) defined it and Miller (1997) implemented, would occur more often in a therapy group setting emphasizing **personal** interaction than in a technical team setting emphasizing **professional** interaction where each team member's personal success is dependent upon the collective success of the team.

Performing Sequences Analysis for the F<N<P three-stage (□=0.05) model revealed that 229 (71%) of the 321 teams generated statistically valid sequences that followed the F<N<P three-stage model. Of these, 161 (50 %) teams also produced an F<N<P average time-of-occurrence sequence of stages. Also, 637 (44%) of the 1,448 individuals experienced a statistically valid F<N<P sequence. This variant does clearly constitute a majority model of team behavior. Because almost 3/4 of the DAU teams experienced a statistically valid F<N<P sequence, the F<N<P model is a reasonably strong contender for a general model of technical acquisition team dynamics. I refer to the F<N<P model as the DAU model.

Certainly, more research is required to evaluate the causal connection between a team's productivity and its experience of the F<N<P development process. More work will be needed to assess the efficacy and general applicability of guiding a team through the F<N<P development process in order to enhance its performance. If the definition and description of Storming is generalized in the survey instrument to include brain storming, perhaps it too would play a part in developing a strategy to optimize team performance.

Because the Norming and Performing behaviors seemed to be intermingled on the timeline (on the average, their means are separated by about 2.5 timeline units), differentiating between the first (F<N<P) and second (F<P<N) most commonly experienced sequence is problematical. Consequently, a two-stage model F<N/P (Forming occurs before Norming, and Forming occurs before Performing) that combines both should represent the single most widely experienced sequence. The Sequence Analysis (□=0.05) was applied to the two-stage model F<N/P. The results indicate that 290 (90.34 %) of the 321 teams had a statistically valid experience of the F<N/P sequence. This variant clearly constitutes a strong model of DAU team behavior. In addition, 895 (62%) of the 1448 individuals also experienced a valid F<N/P sequence. Unfortunately, a simple two-stage model (first a team experiences Forming, and then it experiences everything else) does not provide much information about how one might possibly optimize team productivity other than make sure that every team thoroughly accomplishes Forming at its beginning.

Figure 8 shows that for all three sequence models, above-average teams produced the most statistically significant results followed by average teams, while below-average teams produced the fewest statistically significant results. The data shows consistent descending stair-stepped results in quantity of sequences generated for each team dynamics model as the teams' rating moves from above average to below average.

Sequence	Rating	Number	Percent
F<S<N<P	Above Average (145)	6	4.14%
	Average (151)	0	0
	Below Average (25)	0	0
F<N<P	Above Average (145)	114	78.62%
	Average (151)	102	67.55%

	Below Average (25)	13	52%
F<N/P	Above Average (145)	138	95.17%
	Average (151)	131	86.75%
	Below Average (25)	21	84%
Sequence	**F<S<N<P**	**F<N<P**	**F<N/P**
Correlation	**0.95**	**0.99**	**0.95**

Figure 8. Instructor Evaluation vs. Teams Producing Statistically Significant Sequences

A chi square r x c contingency test was performed to determine the correlation between instructor assessment and a team's probability of producing one of the three sequences of Tuckman stages (F<S<N<P, F<N<P or F<N/P). The correlation numbers given in Figure 8 are the probabilities that the populations are not independent—i.e., the probability that there is a relationship between a team's performance and the model of team dynamics followed by that team. Correlations of 0.95 or greater are considered to represent a relationship between populations that is statistically significant. The more productive and successful a team was, the more likely they were to observe one of the three sequences of Tuckman stages assessed by this research.

After generating a distribution of stage time-of-occurrence data, it was noticed that the stage times-of-occurrence for all 321 teams tended to group together. In other words, all the DAU teams, regardless of their task or duration, experienced the Forming, Norming, and Performing stages at about the same place on the 50-unit timeline. To verify this phenomenon, the Kruskal-Wallis test, as described by Conover (1999) was used to determine if an ensemble of the DAU time-of-occurrence data generated by each of the 1448 individuals for each Tuckman question could be separated into discrete stages. The data indicate that an ensemble of all DAU team members from all teams do collectively experience a discrete sequence of at least three Tuckman stages. This result corroborates the possibility of a universal experience of the Forming, Norming, and Performing stages of the Tuckman model (Tuckman variant 1, F<N<P, DAU Model) at a somewhat predictable fraction of a team's duration. However, the Storming data was spread across the entire timeline, producing no distinct peak. Forming appears to occur at about 25% of the timeline, Norming at about 40% of the timeline, and Performing at about 45% of the timeline.

Primary Conclusions

The development of technical acquisition teams appear to follow a variant of the Tuckman model (F<S<N<P). This model, which I will call the DAU Team Dynamics model, has three discrete stages (F<N<P) and one continuous brainstorming stage that takes place over the entire duration of the team effort. The brainstorming activity can be described as group members challenging each others' ideas and approaches in a cooperative way with the intention of producing a better product or improving the team's process (efficiency and productivity).

This research demonstrates that not only do technical teams follow the DAU model, but that teams following the DAU model produce better products than teams that do not follow this model. It may, therefore, be possible to significantly improve productivity in

technical teams by facilitating the DAU model—that is, to encourage teams to first coalesce as a team and form their intent and structure, then develop their approach, ground rules, and processes, to be followed by assigning tasks and getting the work done—all the while cooperatively challenging, re-evaluating, and improving the overall team process as they work together to accomplish the task they were given. Additionally, one should expect the Forming stage of the DAU model to occur at about 25% of the timeline, the Norming stage to occur at about 40% of the timeline, and the Performing stage to occur at about 45% of the timeline. Establishing a firm causality between following the development structure of the DAU model and improving a technical team's productivity will require additional corroborating research.

Secondary Conclusions

The tools and methods developed in this research project are widely applicable to a broad assortment of team-dynamics research projects. Furthermore, developing a custom set of tools to fit each individual research application is not difficult. These two facts should encourage much additional research.

Though learning how to make teaming more efficient and productive has always been considered of vital importance to large numbers of users, the research process has been so cumbersome, difficult, inconsistent, and lengthy, that the field has languished (relative to its importance) for decades. Now that this research project has developed a statistically and scientifically rigorous process that enables the assessment of a large number of teams relatively easily and quickly, it is hoped that the pace of progress will accelerate. The analysis engine and methodology developed for this project provides a general model for facilitating low-budget, quick turn-around, high-yield, and statistically rigorous research focusing on various team types, settings, sizes, durations, compositions, and configurations. Fortunately, an instrument and its associated analysis engine once developed can easily be used by others to perform similar research in different settings, with different populations, with different types of tasks, and with teams of different sizes and durations.

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