This item was submitted to [Loughborough's Research Repository](#) by the author.
Items in Figshare are protected by copyright, with all rights reserved, unless otherwise indicated.

Toward an understanding of culture and the performance of teams in complex systems

PLEASE CITE THE PUBLISHED VERSION

<http://dx.doi.org/10.1109/JSYST.2012.2206153>

PUBLISHER

© IEEE

VERSION

AM (Accepted Manuscript)

LICENCE

CC BY-NC-ND 4.0

REPOSITORY RECORD

Hodgson, Allan, Ella-Mae Hubbard, and Carys E. Siemieniuch. 2019. "Toward an Understanding of Culture and the Performance of Teams in Complex Systems". figshare. <https://hdl.handle.net/2134/13297>.

This item was submitted to Loughborough's Institutional Repository (<https://dspace.lboro.ac.uk/>) by the author and is made available under the following Creative Commons Licence conditions.

For the full text of this licence, please go to:
<http://creativecommons.org/licenses/by-nc-nd/2.5/>

Towards an Understanding of Culture and the Performance of Teams in Complex Systems

Allan Hodgson, Ella-Mae Hubbard and Carys E. Siemieniuch

Abstract— Systems are becoming ever more complex, and the practice of systems engineering is becoming more formalized. However, this formalization is aimed primarily at the technical and process components of complex systems and systems of systems. National cultural variations in the human components of such systems (typically functioning as groups or teams) are not typically included in the formal specifications and, as a result, the technical end-products do not fully compensate for these variations.

This paper provides an introduction to culture, its sources, its measurement and its effects on team performance. It presents a summary of the research literature on culture and teams, and an overview of a set of pilot studies carried out by the authors. It then describes a methodology and software tool developed by the authors for the assessment of the cultural traits of team members and the estimation of the effects of team member culture on team performance. The paper concludes that, despite some disparities in the results of research studies, sufficiently strong relationships between culture and team performance have been established to justify the development of culture-sensitive team performance prediction tools.

Index Terms—Teams, systems engineering, culture, cultural diversity, Hofstede, team culture tool.

I. INTRODUCTION

AS systems become more complex, systems engineering professionals increasingly turn to formal, computer-supported systems engineering modeling methods. However, systems designers still largely adopt the ‘left-over principle’ [1], where the human operators’ tasks are defined by default as the ‘residual functions’ that cannot be effectively automated. In order to make optimum decisions in the allocation of functions to humans, it is necessary to represent humans in systems models. Current systems models are largely lacking in these ‘human views’ and, as a result, systems engineers produce detailed performance specifications for technical systems, their components and processes, but do not produce (and cannot obtain) the equivalently-detailed specifications for people and their processes. Human

factors guidelines constrain the specification of operators’ physical and cognitive limitations (i.e. what people *can* do); however, *cultural* factors play a significant part in what humans *will* do in a given circumstance.

Most complex systems depend on human teams for their successful operation. Team member interactions depend not only on their educational and training backgrounds, but also on their cultural backgrounds, their cultural differences and the types of tasks they are assigned. In addition to the cultural traits of system users, the cultural traits (or assumptions) built into technical systems by engineers should be considered; technical systems are *not* culture-free.

The purposes of the work described in this paper are three-fold. Firstly, the work is intended to improve our understandings of the effects of team member cultures on various aspects of team performance, across a range of team types; to this end, a literature survey and several pilot studies have been carried out by the authors. Secondly, it is intended to use this improved understanding to contribute to the development of a tool that will enable the selection of team members to be aligned more closely to the performance requirements placed on them. Thirdly, it is intended to develop variants of the above tool that will assist in the specification of complex systems, in order to ensure that the cultural constraints of proposed users are taken into account.

Section II of this paper provides an introduction to culture, its sources and its measurement. Section III provides an overview of the literature on culture and its measurement. Section IV describes pilot study work carried out by the authors. Section V describes the culture tool developed by the authors and Section VI describes proposed further work. Section VII summarizes the authors’ work on culture and its implications.

II. CULTURE

The term ‘culture’, as used in this paper, relates to the sets of values, preferences, beliefs, assumptions, rituals and behaviors that groups or societies develop and share that, in turn, guide individuals.

A. Sources of culture

The main sources of culture include ethnicity (related to the groups and/or nations within which an individual grows to adulthood), organizations (the schools, clubs and companies that an individual attends or is part of) and professions (the trades or professions that an individual spends his or her

This work was supported in part by the UK Engineering and Physical Sciences Research Council.

A. Hodgson, E. Hubbard and C. E. Siemieniuch are with the School of Electronic, Electrical and Systems Engineering, Loughborough University, Loughborough, LE11 3TU, UK (e-mail: a.hodgson@lboro.ac.uk, e.hubbard@lboro.ac.uk, c.e.siemieniuch@lboro.ac.uk)

working life carrying out).

The ethnic culture of a group or society develops over many generations and, in a stable environment, improves that group's or society's survivability. An individual is immersed in his or her ethnic culture from birth, and absorbs it unconsciously; as Dennett [2] points out, any human baby can be relocated to any other culture in the world, and will then adapt to that culture (and language) as effectively as a child born to members of that culture. Due to this unconscious programming, ethnic culture, at the level of the individual, can be regarded as 'firmware of the mind'; few adults are aware of the underlying culturally-based assumptions and values that drive them to behave as they do, and they can therefore be ill-prepared to interact with people from different cultures. Note that, in the remainder of this paper, the authors use *national* culture as an imperfect substitute for ethnic culture because the majority of data on cultural traits has been collected at the national, rather than ethnic, level.

Whereas national culture affects the underlying values, beliefs and assumptions of individuals, organizational culture affects individuals at a shallower level, resulting primarily in adaptations of behavior; individuals adapt reasonably rapidly to differing organizational cultures, but perform with reduced effectiveness if such cultures run counter to their national cultures. Organizational culture emerges out of an organization's history, founder leadership styles, products, services and the national cultures of its employees. Hall and Hall [3] provide an excellent comparison of the national cultural differences between Germans, French and Americans, the effects on their organizations and the resultant misunderstandings that arise during cross-border collaborations; Schein [4] provides an analysis of various American, German and Swiss organizations, and the differing effects of their founders, products and nationalities on their organizational

professional aviation culture. Figure 1 illustrates the balance of values and practices for various 'levels' of culture; national culture is dominated by deep-seated values, which are very difficult to change, whereas organizational culture consists primarily of practices, which are more amenable to change.

B. Quantitative measures of national culture

As stated in the introduction, the cultural traits of individuals and teams affect the performance of the complex systems that they design or utilize. It is therefore important to take cultural traits into account when designing such systems. The systems engineering process requires reliable data, usually expressed in quantitative form, in order to achieve adequate accuracy at the various stages – requirements analysis, functional analysis, synthesis, etc. It is therefore desirable to be able to measure culture in a quantitative fashion, and to quantify the effects of that measured culture on performance. This quantification of the cultural traits of individuals and teams involved in the design and operation of complex systems can be achieved by utilizing 'cultural dimensions' via which nations or teams can be positioned in cultural space.

Several cultural frameworks (sets of cultural dimensions) have been examined by the authors, including those of Triandis [5], Hofstede [6], Trompenaars [7] and the GLOBE project [8]. Following this examination, the authors have chosen to utilize Hofstede's original four-dimension cultural framework in their work, primarily because of the large number of research studies that have utilized it and the large number of validations that have supported it, for example [9], [10], [11] and [12]. A further reason for choosing Hofstede's framework is based on the clarity and effectiveness with which Hofstede has answered criticisms of his framework, typically refuting very effectively his critics, for example [13], [14]. Hofstede's original four dimensions are briefly summarized in Table 1; readers can find detailed descriptions in chapters 3 to 6 of [6].

Hofstede's original surveys took place in the late 1960's, and were focused on IBM employees of all grades in more than forty countries. Later, as a visiting lecturer at IMEDE (Lausanne, Switzerland), Hofstede found that the international students on his courses (who were managers at public and private organizations) produced extremely similar results (country by country) to those in the original IBM surveys. Other researchers have since provided culture scores for many additional countries and regions to those in Hofstede's original survey.

Hofstede's original four-dimensional framework was later supplemented by two further dimensions. Long-term orientation (LTO) emerged from an analysis of samples from the Chinese Value Survey during 1985; see [15] and [6], Ch. 7. Indulgence versus restraint (IVR) emerged from Minkov's analysis of the World Value Survey, see [6], Ch. 8. However, LTO scores were only available for 23 countries when the authors' work began, and country scores for the IVR dimension were not available at that time. Therefore the

Fig. 1. Hofstede's 'balance of values and practices' (adapted from [6], p.347)

cultures.

Professional culture is situated between organizational and national culture in terms of its effects on individuals. However, as with organizational culture, if professional culture runs counter to the individual's national culture, then problems can arise. Critical elements of professional culture may need repeated reinforcement; for example in the aviation transport industry, aircrews are subject to regular simulation training exercises to ensure retention of desirable aspects of

authors have not utilized these two dimensions to-date.

The authors recognize that Hofstede's framework does not represent a complete picture of culture. However, the framework enables the capture of cultural traits of groups that have useful predictive values.

TABLE I
HOFSTEDE'S CULTURAL DIMENSIONS

Cultural dimension	Description
Individualism (IDV)	The degree to which an individual puts his or her priorities above the priorities of the group (excluding immediate family). Individualists (high IDV) tend to speak factually, take responsibility for their actions and respond to personal incentives. Collectivists (low IDV) conform to their group norms and in return receive the protection of that group; they avoid confrontation and loss of face; diversity and dissent are discouraged. Collectivists respond best to group (rather than personal) incentives. Examples (countries and regions): Low IDV: Central America, Pakistan, China, Arab countries. High IDV: Anglo & Northern European countries, Italy.
Power distance (PDI)	The degree to which power is concentrated with those in formal authority. In low PDI countries, decisions tend to be made by those with the appropriate knowledge; in high PDI countries, decisions are always made by those in authority, and upwards communication is difficult. Examples (countries and regions): Low PDI: Israel, Scandinavian, Anglo & Germanic countries. High PDI: Central America, Malaysia, China, Philippines, Arab countries.
Masculinity (MAS)	The degree to which there are differences between male and female roles. In masculine societies, challenge, competition and recognition are more important, whereas in feminine societies, quality of life, co-operation and relationships are more important. Examples (countries and regions): Low MAS: Costa Rica, Scandinavian countries. High MAS: Japan, Hungary, Austria, Italy.
Uncertainty avoidance (UAI)	The degree to which a cultural group feels uncomfortable in ambiguous or unclear situations. Members of high UAI cultures will seek to reduce uncertainties, in part by legislation, formal rules and behavior. Members of low UAI cultures tolerate or even enjoy ambiguity and uncertainty. Examples (countries and regions): Low UAI: Anglo, Scandinavian countries, India, China, Jamaica, Singapore. High UAI: Central America, Japan, Portugal, Greece.

III. A SURVEY OF THE LITERATURE

The authors have analyzed research literature on the effects of culture on team performance. Although conflicting results are reported, research surveys and meta-studies have identified culture-related trends; examples from the literature survey are reported in the following subsections.

A. Individualism (IDV)

Goncalo and Staw [16] report that high average collectivism (low average IDV) amongst a team's membership tends to lead to increased co-operation and conformity but reduced

creativity and innovation; such (low-IDV) team members consider the achievement of maximum agreement amongst team members to be of more importance than an optimum solution (as measured externally to the team). However, Watson et al. [17] report that a team consisting of collectivists who are not from the same social group, and are not familiar with each other, may become dysfunctional.

B. Power distance (PDI)

Helmreich and Merritt [18] carried out a five year survey of more than 17,000 commercial airline staff from 23 countries, including captains, first officers, flight attendants, maintenance staff, managers and trainers; they report that low PDI aircraft crew members were found to be more willing to make their views known to the captain than were high power distance crew members, thus implying that high power distance hinders communication in the cockpit. They reported similar issues with medical surgery units.

Jing et al. [19] report that the most important cultural variable associated with aircraft accidents is authoritarianism (related to Hofstede's PDI dimension); Taiwanese and mainland Chinese cultures score highly in authoritarianism and, in many cases, cockpit voice recordings from crashed aircraft have indicated major communication difficulties between copilot and captain during the period before the crash, thus confirming Helmreich and Merritt's findings.

In recent years, European low-cost carriers have increasingly employed non-European flight crews, usually from higher power distance cultures, and this has raised concerns with regard to flight safety [20].

C. Masculinity (MAS)

In low MAS countries, the emphasis within a team is typically on relationships and agreement-seeking, rather than on outcomes that meet the goals externally imposed on the team. This emphasis, which is similar in some ways to that of collectivists, can be damaging when the team is set high creativity goals, e.g. to develop 'blue skies' proposals such as 'the road vehicle of the future'. The research of Halkos and Tzeremes supports this view; their study of the effects of national culture [21] demonstrates that innovation efficiency is positively correlated with MAS, up to a MAS score of about 75. An earlier study, by Kedia et al. [22], found that R&D performance is higher in countries that are high in MAS and low in PDI.

D. Uncertainty avoidance (UAI)

Surveys by Gudykunst et al. [23] and Edelman et al. [24] demonstrate that members of high UAI societies tend to suffer a high level of social anxiety, which discourages them from contributing in public and group situations. Shane [25] describes a study of the attitudes of 4400 individuals (in 68 countries) to four 'innovation championing' roles; his study demonstrates that individuals with low UAI scores are more comfortable with these roles than individuals from high UAI societies.

Kaasa and Vadi [26] examine the effects of differing

European cultures on innovation activity, in particular patenting. They find the strongest relationship to be the negative one between UAI and indicators of patenting intensity; in addition, they find that PDI and MAS have lesser negative relationships with these indicators.

Burke et al. [27] report that training programs in high UAI cultures consist largely of classroom learning at the expense of 'hands-on' participation, when compared with programs in low UAI cultures; this results in reduced training effectiveness, particularly in key areas such as safety and emergency response. Klein et al. [28] report that the threshold for initial reaction to anomalies tends to be higher for high UAI individuals than for low UAI individuals, resulting in delayed reactions by high UAI individuals. Such delays may be beneficial in low risk situations, but they can increase the risk of catastrophic failure in high risk situations, for example in the case of component or system deterioration in aircraft, power stations or refineries.

E. Combinations of cultural dimensions

Certain combinations of cultural dimension scores result in an exacerbation of performance and safety problems, in particular when utilizing complex systems created by designers and engineers of very different cultural backgrounds. For example, the 'design templates' for most transport systems, power generation systems and refinery systems have been developed primarily by low PDI, high IDV, low UAI western engineers – these designs include technical systems, procedures and, in addition, presumptions of high levels of team member interaction. When these systems are utilized by high PDI, low IDV, high UAI users, then the result will be reduced effectiveness and increased risk levels. An example of such an increase in risk is demonstrated in the findings of Soeters and Boer [29]; they present the results of a study into aircraft losses in fourteen NATO air forces between 1988 and 1995. They report strong positive, statistically validated correlations between low IDV, high PDI, high UAI scores and increased accident rates. This discrepancy between air forces occurs despite much commonality across NATO in terms of aircraft fleets, standard operating procedures, regulations, training and exchange of personnel.

Incident reporting programs have been developed to document aircraft fleet errors, procedures, etc., in order to improve safety *before* accidents occur, e.g. the US Aviation Safety Action Program (ASAP). These have been successfully introduced in the USA and Europe, but have been much less successful in high PDI, low IDV Asian countries due to a 'punishment' culture; for example Lee and Weitzel [30] found that Taiwanese crews' usage of the TACARE aviation incident reporting program was low because air carrier managers would attempt to identify and punish flight crews who were responsible for these incidents, rather than attempting to eradicate the root causes.

A combination of high PDI and high UAI results in major barriers to the implementation of effective safety programs;

safety cultures and safety programs cannot be transplanted from culturally very different locations. A study by Infortunio of industrial fatal accident rates over thirty years across seven industrial categories and 43 countries [31] demonstrates that fatal accident rates are correlated to high PDI, low IDV and high UAI; he proposes $\log PDI/IDV$ as the key variable in the construction of a safety culture model.

F. Cultural diversity

The literature on the effects of cultural diversity within teams is of limited value because the most commonly used methods of calculating team national or ethnic cultural diversity, e.g. the *Shannon index*, *Simpson's index* or *Blau's index*, are based on the weighted number of nationalities in the team. As a result, a team consisting of (say) British, Irish, Australian and Canadian members, would be considered to have the same cultural diversity as a team consisting of Chinese, Guatemalan, Norwegian and Pakistani team members. This assumed equivalence is clearly incorrect, as the former team would share a language and considerable cultural heritage, whereas the latter would share little. The authors' calculations of cultural diversity are based on the quantitative differences between team members' actual cultural dimension scores; it is believed that this estimate of cultural diversity is much more accurate; in addition, it enables us separately to examine diversity in each of Hofstede's four cultural dimensions. The widespread use of insensitive measures of cultural diversity explains in part the wide variance in reported effects of diversity, examples of which are described in the following paragraphs.

From their study of European research teams, Barjak and Robinson [32] conclude that the most successful teams had a strong domestic base, a moderate level of cultural diversity and some active international collaboration; note that they use the Shannon diversity index to measure diversity. Stahl et al.'s meta-study of 108 empirical studies [33] reports that cultural diversity in teams produces increased creativity and satisfaction but increased task conflict and decreased team member integration; the overall effect of diversity on team performance appears to be close to zero, probably due in part to the wide range of team types in the data. Vodosek's study of 76 science research groups [34] reports that increased diversity leads to increased intragroup conflict and reduced outcomes.

Schwenk's exploratory study [35] concludes that a degree of conflict appears to be beneficial; if conflict is entirely absent, teams tend to consider a smaller range of options and thereby to become less innovative; there appears to be an optimum level of cultural diversity that generates the highest level of creativity or innovation. However, a study by Earley and Mosakowski [36] finds that low and highly diverse groups outperform moderately diverse groups. Hambrick et al. [37] report that team cultural diversity does not bring direct benefits; however, culturally-diverse teams are unavoidable in a modern multinational company, and can be useful in training members to work across cultures – an increasingly important

capability.

It appears that the net effects of cultural diversity are limited, and dependent on the degree of diversity and the nature of the team or group tasks.

G. Potential pitfalls

It is important to bear in mind that cultural differences represent just one of many potential explanations for differences in performance and accident rates among nations and groups. Hofstede [38, page 115] refers to two papers, one by Ramsden [39], the other by Weener and Russell [40]; the statistical analyses in these papers demonstrate strong correlations between accident rates and national PDI scores. When Hofstede added gross national product (GNP) per capita to the datasets and conducted a reanalysis, per-capita GDP was found to be the dominant variable; high PDI and low IDV have strong correlations with low per-capita GDP. This could be seen as a case of *fundamental attribution error* in the two papers, i.e. the allocation of crash causes to cockpit crews' internal dispositions rather than to the external situations. Nevertheless, there is strong statistical evidence from relatively high per-capita GDP countries (for example South Korea and Taiwan) that high PDI and low IDV combine to cause inadequate cockpit communication and high aircraft crash rates; this evidence is supported by cockpit voice recordings, as stated earlier [19].

Statistics provide correlations, not causal links. Causally, it would be reasonable to hypothesize that the primary effects of low per-capita GDP are on aircraft maintenance and airport facility quality, rather than on the effectiveness of flight communications. A detailed analysis of airline crash causal factors would confirm or refute such a hypothesis; this issue is further addressed in Subsection VI.A.

H. Existing team culture methods and tools

A substantial quantity of academic literature has been published relating to the effects of culture on the performances of teams, although much of it is qualitative and partial in its coverage; the authors have presented examples of this literature in the earlier parts of this section. By way of contrast, there is little academic literature on methodologies and tools for the prediction of the effects of team member culture on team performance or for the guidance of team builders, other than qualitative checklist-based approaches. There are many bespoke, consultancy-based multicultural team building programs advertised in the media, but little supporting theory or evidence is available to enable evaluations of them.

Sivakumar and Nakata [41] describe a culture-based team optimization model that is limited to global new product teams (GNPTs). This model splits GNPT activities into two major stages – *initiation* (idea generation, screening, concept testing) and *implementation* (product design, test marketing, market introduction). Sivakumar and Nakata postulate that culture dimension 'slopes' that are positive for initiation are negative for implementation, and that the relative importance of

initiation to implementation (high for radical innovations, low for incremental innovations) will guide the derivation of overall optimum culture dimension scores for a particular innovation situation. Knowing these 'ideal' scores, team builders should be able to assemble an optimum team. However, it is not clear how the above 'slopes' are to be obtained and, as stated by the GNPT model's authors, the division of GNPT activities into two stages – initiation and implementation – is not universally agreed.

The authors of this paper have previously developed the Soft Factors Modeling Tool (SFMT) [42]; this tool is primarily intended for the cultural evaluation of missions in military environments. The SFMT enables the evaluation of up to three 'entities' in terms of their alignments with proposed mission tasks and environments; these entities can be any combination of individual, team and/or organization; the SFMT does not evaluate internal team diversity and intra-team issues, e.g. how effectively team members interact with each other and make decisions in order to perform team tasks.

IV. STUDIES CARRIED OUT BY THE AUTHORS

The authors have carried out a range of pilot studies and surveys of multicultural teams and groups. In order to gain an understanding of the effects of cultural traits on teams, it has been necessary to examine a wide range of team types whose environments provide various levels of constraint, predictability, risk, etc., and demand various levels of communication (e.g. in terms of rapidity, clarity and complexity), decision-making, creativity, innovation, etc. This approach has enabled the identification of potential trends across team types.

The types of team selected for pilot studies include sports teams, student project groups, research teams, commercial work teams and industrial work teams; the data from these has been supplemented, where feasible, by data collected from the literature. The pilot study results are described briefly in the following subsections.

A. Sports team performance – the English Premiership

The English Premiership attracts many of the World's most gifted soccer players and, as a result, most Premiership teams are highly multicultural. The authors carried out an analysis of all 380 match fixtures that took place during the English 2010-2011 season.

Following discussions with sports researchers, 'shots-on-goal' was chosen as the measure of team performance rather than win/draw/lose or goal difference; shots-on-goal is a more accurate measure of performance and is less affected by refereeing errors. The longer term relationship between shots-on-goal and goals-scored has been demonstrated in the work of Reep and Benjamin [43]; also, Miklos-Thal and Ullrich [44] utilize shots on goal as a key measure of player performance.

For each Premiership match, the capability rating of each player, weighted by his period of play, was taken into account

in order to assign an overall skill level to the home and away teams; in addition, the weighted cultural dimension scores and cultural diversity scores were calculated (based on Hofstede's framework) for each team.

Statistical results of the analysis indicate that the most important cultural dimension is uncertainty avoidance (UAI). A high team UAI score (relative to those of the opposing teams) has a positive effect on team performance over the season; in addition, high UAI diversity and high masculinity (MAS) scores also improve team performances to a lesser extent. The above cultural factor scores were found to predict English Premiership team performance over the season (in terms of goal difference) almost as effectively as team talent scores; the combination of cultural and talent factors provided a high level of predictability over the season.

B. Student group performance

Data was collected covering seven years of student projects in Loughborough University's engineering departments. Taking account of average student ability within each group, high UAI student groups were found to perform less well than low UAI groups. The effects of other cultural dimensions were not statistically significant at the five percent level.

C. University research team performance

Quantitative data was collected based on the UK's Research Assessment Exercise (RAE) that took place in 2008. In particular, two research areas were investigated – chemical engineering and physics. This work is only part-completed, but results to-date indicate that IDV was positively associated with scores in the 2008 RAE.

D. Airline accident rates

The authors have evaluated airline accident statistics based primarily on data obtained from AirSafe.com [45]; this data, which covers the period 1970 to 2009, contains more than a decade of additional information to that which Hofstede re-evaluated (see Section III G: *Pitfalls*). The authors' statistical analysis reveals that per capita GDP remains the largest single factor in crash rates, thus confirming Hofstede's conclusions [6, page 115]. Following correlation tests, PDI and IDV were removed from the analysis, resulting in a statistical model in which per capita GDP (negative relationship) plus UAI (positive relationship) accounted for 45% of crash variability.

Note that the cultural factor scores used for the above analysis were those of the airline's primary country, not specifically those of the flying crews. Many non-western airlines employ a significant proportion of western flying crews (who bring their own national and professional cultures); the above analysis could offer insights into the effects of per capita GDP and national culture on aircraft accident rates via their effects on maintenance regimes, safety cultures and airport resource qualities. This issue will be explored further (see Subsection VI.A).

E. Commercial and engineering work team performance

Qualitative and quantitative data has been collected from

commercial and engineering work teams; several of the latter teams included systems engineers. The results show general agreement with published meta-studies such as that of Stahl et al. [33], i.e. that cultural diversity can produce a wider range of ideas, but typically results in greater conflict; several interviewees commented about conflicts arising from differences in *organizational* culture. However, a significant proportion of apparent team performance failures were stated by interviewees to be due to external reasons, for example:

- the team goals were known to be infeasible,
- an external manager tasked his or her team representative to prevent certain outcomes, or
- Insufficient resources or authority were provided for the achievement of the team goal(s).

F. Key findings from the literature and pilot studies

The key findings from the literature and the authors' pilot studies are summarized below.

1) Individualism (IDV)

Low IDV leads to increased co-operation and striving for conformity within teams; this may improve team social processes but tends to reduce innovation and creativity.

Low IDV individuals have difficulties communicating disagreements and problems due to issues of face; this may lead to delays at critical times.

2) Power distance (PDI)

High PDI impedes rapid communication, which may have serious ramifications during critical situations, e.g. aircraft engine failure or patient trauma on the operating table. When high PDI and low IDV are combined, communications are impeded further.

3) Masculinity (MAS)

Low MAS can have a similarly damaging effect on innovation as low IDV because team members strive for agreement and harmonious relationships; high creativeness and innovation are linked to above average (but not extreme) MAS. High MAS can lead to aggressive behavior that deters less masculine team members from contributing.

4) Uncertainty avoidance (UAI)

High UAI has a negative effect on the implementation of safety culture, in part because it discourages practice and training exercises in favor of classroom learning; this results in team members being unprepared when emergencies or deviations from the norm occur, e.g. on aircraft flight decks, in power plants and in critical medical situations. In team sports, the authors' analysis of soccer matches has shown that high UAI is beneficial. However, in areas that require originality of thought, in particular where innovation is required, high average UAI appears to be a major disadvantage to a team. Also, high UAI discourages the adoption of organizational roles that support innovation.

5) Cultural diversity

Neither the literature nor the researchers' pilot studies reveal consistent output performance affects related to cultural diversity. Although a degree of cultural diversity appears to be associated with a wider range of ideas and increased

conflict, these do not translate into clear trends in terms of team performance

(national PDI=77) *could* be of lower power distance than a team consisting of Americans (national PDI=40).

Fig. 2: Team Culture Tool (TCT) – process and data flow

V. THE TEAM CULTURE TOOL

The authors' *Team Culture Tool* (TCT), see Figure 2, assesses cultural profiles within single culture or multicultural teams or groups, and determines the matches (or discrepancies) between these profiles and the task requirements. At present, the TCT is intended primarily to inform system builders about issues faced by culturally-different system operators; to this end, the authors also intend to develop the tool further as an adjunct to the systems engineering (design) process. The TCT can also be utilized for the assessment of systems engineering/design teams; however, in this situation it is currently intended to be used in conjunction with other tools developed by the researchers, see Subsection V.B.

The Team Culture Tool (TCT) is not intended to predict the 'absolute' performances of individual teams; it is intended to highlight where (and why) culture is *likely* to be a significant factor in underperformance or heightened risk. Default national cultural scores (as used in the TCT) represent average scores, but the standard deviations of these scores may be high in some countries particularly if they contain several distinct ethnic groups; as a result, a team consisting of Indians

A. Utilizing the tool

The bracketed numbers and letters in the following description of the operation of the TCT refer to the boxes in the flow diagram of Figure 2.

The user selects a team (1) and enters the team member details (nationalities and educational levels) into the TCT (2); the TCT derives default cultural dimension scores for the team members and, from these, calculates four mean cultural dimension scores (PDI, IDV, MAS and UAI) and a corresponding set of cultural diversity scores for the team; this is the team default cultural profile (D2). Note that the user can also enter dual nationalities or team member actual culture scores, if known. The user then describes the team purpose, requirements, etc. (3), by entering weights for several sets of task-related sub-factors and their higher level factors.

All the above sub-factors have estimated optimum cultural scores and cultural diversity scores associated with them (based on the researchers' literature surveys and pilot studies); these optimum scores are stored in the context master table (D0). In process step (4), the differences between these optimum cultural scores (D0) and the actual team cultural scores (D2) are calculated for each sub-factor and weighted by their importance (based on the weights of (D3)) to produce numerical and graphical (traffic-light) representations of

potential team performance discrepancies (D4a). In addition, the average *team cultural score discrepancies* are calculated (D4b). At this stage (5), it is necessary to make a decision to accept the current team or to change it, based on the potential team performance discrepancies (D4a); guidelines are provided for this decision. If the user chooses to change the team membership (6), guidelines are also provided to enable the improvement of the team culture for the task in-hand by selecting team members with different cultural scores; this selection is based on the team cultural score discrepancies (D4b) and the current team member cultural scores (D2).

To minimize user workload, a set of stereotype team context tables is also provided for common team/task combinations; these provide an instant answer (if selected) following user input to the team culture profile table (2).

When using the tool for systems engineering design purposes, the systems engineer is unlikely to know the details of the individuals who will operate the system after it is installed; therefore the engineer has no choice but to assume default (national) cultural dimension scores, e.g. for Taiwanese flight crews or Nigerian oil terminal workers.

B. Integration of the TCT with other tools

The authors are members of the Engineering System of Systems (ESoS) research group at Loughborough, which is developing a portfolio of systems modeling tools including process modeling, role modeling and team reliability modeling [46]. The team culture tool (TCT) does not currently differentiate between different team role types because team roles are handled via the researchers' *Role Matrix Technique* (RMT) and *Performance Evaluation and Assessment for Teams* (PEAT) human factors tools. However, neither of these two tools currently captures any leadership-related *cultural* factors or capabilities; these are reported in the literature to have a significant effect on team performance [47], [48]. See Subsection VI.C for further comments.

C. Evaluation of the Team Culture Tool

An initial evaluation of the TCT has been against merchant shipping crew fatality rates for high GDP countries; high TCT discrepancy scores (indicating cultural mismatches) were associated with higher fatalities. However, a full program of validation and verification is required prior to serious application of the tool.

VI. FURTHER WORK

The authors recognize that additional data must be obtained in order to clarify further the relationships between culture and team performances, and to evaluate the team culture tool (TCT). Further work therefore focuses on the validation and verification of the tool in various environments. This will test the internal integrity of the tool and ensure that it is fit for purpose in a range of team contexts.

A. Data collection and analysis

In furtherance of the aim of tool validation and verification, the authors will firstly collect and analyze data based on the following team types:

Organized action teams: Examples of these include aircraft cockpit crews, surgery teams, army patrols, fire-fighters and expeditionary teams. Many of these are involved as operators within complex systems. This work will include a detailed evaluation of air crash data in order to clarify issues brought up in subsections III.G and IV.D.

Industrial innovation teams: In particular, new product development teams. These are primarily industry teams (sometimes multi-company), not joint industry/client teams.

Large complex project teams: A variety of complex system teams will be addressed via our collaborators. These will primarily be within the defense sector, and will include joint industry/client teams, but at this stage it is not clear as to the sizes or types of complex systems they will be working on. The data from these teams (and that associated with several industrial innovation teams) will be collected using web-based questionnaires, face-to-face semi-structured interviews and via the provision of the prototype team culture tool posted on the research group website at Loughborough University. Website access to the tool will enable a range of potential tool stakeholders to interact with the latest version and provide feedback information directly to the developers, i.e. this will constitute beta-testing of the tool.

University student groups: The mix of cultural backgrounds provides insights to the effects of culture on team conflict, social loafing and innovation performance.

University research groups: These teams provide very high levels of cultural diversity and demand high levels of creativity and originality. The researchers will be able to collect detailed quantitative and qualitative data.

Sports teams: The original work of the authors on soccer teams produced unexpected results with regard to uncertainty avoidance (UAI). The data will be further analyzed to determine whether the relationship between UAI and performance applies to all team members or, as logic suggests, applies primarily to the teams' defenders. In addition, subject to data availability, national soccer team performances will be evaluated against cultural dimension scores.

Issues and concerns: There are issues with regard to non-cultural factors, including the fundamental attribution error (see Subsection III.G); the authors are following a systems approach in their work, and external influencing factors, where recognized, will be taken into account. There are further statistical issues, particularly with regard to complex system project teams due to the small sample size and high level of variation in team tasks. Therefore, the primary purpose of the data collected from these teams will be to test the TCT, rather than to establish further statistical relationships between culture and performance.

B. Team and task taxonomies

The authors have found the team and task taxonomies

presented in the literature to be inadequate for the purposes of the work described in this paper; the TCT currently utilizes a simple team taxonomy, (based on four main team types), captured as stereotypes. Team/task taxonomies will be developed during 2012 to improve the sensitivity of the TCT, particularly with regard to project teams.

C. Capturing the team leader role

As stated in Section V.B, the TCT does not currently capture individual team roles because these are captured by other tools produced by the researchers. However, it is recognized that the cultural aspects of the team leader's capabilities have a major effect on overall team performance. Therefore, the researchers are examining several approaches to enable the future inclusion of culturally-related leadership factors (e.g. cultural experience and cultural intelligence) within the TCT.

D. Organizational culture

The current version of the TCT incorporates national culture and education (the latter as a proxy for occupational culture). However, organizational culture has a significant effect on performance and safety, and it is therefore intended to include it in a later version of the TCT. Hofstede et al. describe a framework of six organizational culture dimensions that emerged from the analysis of a survey of twenty units representing five Danish and five Dutch organizations [49]. Although the above framework is based on a study in only two countries, it represents a potentially useful basis for the measurement of organizational cultures in Anglo and North European countries.

VII. DISCUSSION

A number of broad relationships have been confirmed or established between team culture and team performance; in particular, the authors' pilot studies have highlighted the positive and negative effects of uncertainty avoidance on the performances of differing team types. The effects of culture on team behavior are sufficiently strong to alter significantly the performances of complex systems and, in particular, the performances of safety-critical systems. However, these culture-related affects and risks are typically unrecognized by system designers and, as yet, they are neither represented, nor representable, in formal system specifications.

Based on findings from the literature and their own pilot studies, the authors have developed a practical culture-based tool that enables users to evaluate a proposed or existing set of team members against the team's purpose and its associated tasks. No other tool has been found in the literature that offers a similar capability, in particular when utilizing team members from multiple cultures.

The authors' pilot studies and tool development activities have to-date concentrated on national culture due to its pervasiveness. However, it is clear that organizational cultures also have significant effects on performance, in

particular safety performance. This additional aspect of culture will be brought into the underlying model of the TCT.

REFERENCES

- [1] J. Andersson, *Automation Strategies in Five Domains – a Comparison of Levels of Automation, Function Allocation and Visualization of Automatic Functions*. Sweden: Chalmers University of Technology, report no. NKS-237, ISBN 978-87-7893-309-6, 2011, 38 pages.
- [2] D.C. Dennett, *Consciousness Explained*. Boston, M.A.: Little, Brown & Company, 1991, 528 pages.
- [3] E.T. Hall and M.R. Hall, *Understanding Cultural Differences: Germans, French and Americans*. Boston, M.A.: Intercultural Press Inc., 2000, 217 pages.
- [4] E.H. Schein, *Organizational Culture and Leadership* (4th ed.). San Francisco: Jossey Bass, 2010, 464 pages.
- [5] T.M. Singelis, H.C. Triandis, D.P.S. Bhawuk and M.J. Gelfand, "Horizontal and vertical dimensions of individualism and collectivism: A theoretical and measurement refinement," *Cross-Cultural Research*, vol. 29, no. 3, 1995, pp. 240-275.
- [6] G.H. Hofstede, G.J. Hofstede and M. Minkov, *Cultures and Organizations: Software of the Mind* (3rd ed.). New York: McGraw-Hill, 2010, 561 pages.
- [7] F. Trompenaars and C. Hampden-Turner, *Riding the Waves of Culture: Understanding Cultural Diversity in Business*, London: Nicholas Brealey Publishing, 1997, 595 pages.
- [8] R.J. House, P.J. Hanges, M. Javidan, P.W. Dorfman and V. Gupta (eds.), *Culture, Leadership, and Organizations: The GLOBE Study of 62 Societies*. Thousand Oaks, CA: Sage Publications, 2004.
- [9] A.I. Naumov, "Measuring Russian culture using Hofstede's dimensions," *Applied Psychology: An International Review*, vol. 49, no. 4, 2000, pp. 709-718.
- [10] M.I. At-Twaijri and I.A. Al-Muhaiza, "Hofstede's cultural dimensions in the GCC countries: An empirical investigation," *International Journal of Value-Based Management*, vol. 9, no. 2, 1996, pp. 121-131.
- [11] K. Brown, "Cultural dimensions of New Zealand entrepreneurial behavior," *Small Enterprise Assoc. 16th Ann. Conf.*, Ballarat, New Zealand, Sept-Oct 2003.
- [12] M. Jones, "Hofstede – culturally questionable?" *Oxford Business and Economics Conference*, Oxford, UK, 2007.
- [13] G.H. Hofstede, "Dimensions do not exist: A reply to Brendan McSweeney," *Human Relations*, vol. 55, no.11, 2002, pp. 1355-1361.
- [14] G. Hofstede, "What is culture? A reply to Baskerville," *Accounting, Organizations and Society*, vol. 28, 2003, pp. 811-813.
- [15] Chinese Culture Connection, "Chinese values and the search for culture-free dimensions of culture," *Journal of Cross-Cultural Psychology*, vol. 18, 1987, pp. 143-164.
- [16] J.A. Goncalo and B.M. Staw, "Individualism-collectivism and group creativity," *Organizational Behavior and Human Decision Processes*, vol. 100, 2006, pp. 96-109.
- [17] W. Watson, D. Cooper, M.A.J.L. Neri Torres and N.G. Boyd, "Team processes, team conflict, team outcomes, and gender: An examination of U.S. and Mexican learning teams," *International Journal of Intercultural Relations*, vol. 32, pp. 524-537, 2008.
- [18] R.L. Helmreich and A.C. Merritt, *Culture at Work in Aviation and Medicine*, Ashgate Publishing Limited, Aldershot, UK, 1988, 301 pages.
- [19] H-H. Jing, J. Lu and S.L. Peng, "Culture, Authoritarianism and Commercial Aircraft Accidents," *Human Factors and Aerospace Safety*, vol. 1, no. 4, 2001, pp. 341-359.
- [20] M. Anderson, D. Embrey, C. Hodgkinson, P. Hunt, B. Kinchin, P. Morris and M. Rose, *The Human Factors Implications for Flight Safety of Recent Developments in the Airline Industry, a Research Study for the JAA: Final Report, Version 2*. Icon International Services Limited, London, 2001.
- [21] G. Halkos and N. Tzeremes. 2011. *The effect of national culture on countries' innovation efficiency*, MPRA Paper 30100, University Library of Munich, Germany, 2011, 21 pages. http://mpra.ub.uni-muenchen.de/30100/1/MPRA_paper_30100.pdf
- [22] B. Kedia, R.T. Keller and S.D. Julian, "Dimensions of national culture and the productivity of R&D units," *Journal of High Technology Management Research*, vol. 3, no. 1, 1992, pp. 1-18.

- [23] W.B. Gudykunst, S.M. Yang and T. Nishida, "Cultural differences in self-consciousness and self-monitoring," *Communication Research*, vol. 14, 1987, pp. 7-36.
- [24] R.J. Edelman, J., A. Asendorpf, V. Contarello, V. Zammuner, J. Georgas and C. Villanueva, "Self-reported expression of embarrassment in five European cultures," *Journal of Cross-Cultural Psychology*, vol. 20, 1989, pp. 357-371.
- [25] S. Shane, "Uncertainty avoidance and the preference for innovation championing roles," *Journal of International Business Studies*, Q1, 1995, pp. 47-68.
- [26] A. Kaasa and M. Vadi, "How does culture contribute to innovation? Evidence from European countries," *Economics of Innovation and New Technology*, vol. 19, no. 7, 2010, pp. 583-604.
- [27] M.J. Burke, S. Chan-Serafin, R. Salvador, A. Smith; and S. A. Sarpy, "The role of national culture and organizational climate in safety training effectiveness," *European Journal of Work and Organizational Psychology* vol. 17, no. 1, 2008, pp. 133-152.
- [28] H.A. Klein, "Cognition in natural settings," in *Cultural Ergonomics, Advances in Human Performance and Cognitive Engineering Research*, vol. 4, M. Kaplan, Ed., Oxford: Elsevier Press Ltd, 2004, pp. 249-280.
- [29] J.L. Soeters and P.C. Boer, "Culture and flight safety in military aviation," *International Journal of Aviation Psychology*, vol. 10, no. 2, 2000, pp. 111-133.
- [30] P.I. Lee and T.R. Weitzel 2005, "Air carrier safety and culture. An investigation of Taiwan's adaptation to western incident reporting programs," *Journal of Air Transportation*, vol. 10, no. 1, pp. 20-37.
- [31] F.A. Infotunio, *An Exploration of the Correlations Between Fatal Accident Rates Across Nations and the Cultural Dimensions of Power Distance, Uncertainty Avoidance, Individuality and Masculinity*, dissertation, Argosy University, Sarasota, USA, 2003, 162 pages.
- [32] F. Barjak and S. Robinson, "International collaboration, mobility and team diversity in the life sciences: impact on research performance," *Soc. Geogr.*, vol. 3, 2008, pp. 23-36.
- [33] G.K. Stahl, M.L. Maznevski, A. Voigt and K. Jonsen, "Unraveling the effects of cultural diversity in teams: A meta-analysis of research on multicultural work groups," *Journal of International Business Studies*, vol. 41, 2010, pp. 690-709.
- [34] M. Vodosek, "Intragroup conflict as a mediator between cultural diversity and work group outcomes," *International Journal of Conflict Management*, vol. 18, no. 4, 2007.
- [35] C.R. Schwenk, "Conflict in organizational decision making: An exploratory study of its effects in for-profit and not-for-profit organizations", *Management Science*, vol. 36, 1990, pp. 436-448.
- [36] P.C. Earley and E. Mosakowski, "Creating hybrid team cultures: An empirical test of transnational team functioning," *Academy of Management Science Journal*, vol. 43, 2000, pp. 26-49.
- [37] D.C. Hambrick, S. Canney-Davison, S.A. Snell and C.C. Snow, "When groups consist of multiple nationalities: Towards a new understanding of the implications," *Organization Studies*, vol. 19, no. 2, pp. 181-205, 1998.
- [38] G. Hofstede, *Culture's Consequences: Comparing Values, Behaviors, Institutions and Organizations across Nations (2nd ed.)*. Thousand Oaks, CA: Sage Publications Inc., 2001, 616 pages.
- [39] J.M. Ramsden, "World airline safety audit," *Flight International*, January 26, 1985, pp. 29-34.
- [40] E.F. Weener and P.D. Russell, "Aviation safety review: Regional perspectives," *22nd International Air Transport Association Technical Conference*, Seattle, WA, USA, 1994.
- [41] K. Sivakumar, C. Nakata, "Designing global new product teams: Optimizing the effects of national culture on new product development", *International Marketing Review*, vol. 20, no. 4, 2003, pp. 397-445.
- [42] A. Hodgson and C.E. Siemieniuch, "The evaluation of cultural factors and their potential effects on military operations," in *Proc. 3rd DTC Technical Conference*, Edinburgh, 2009.
- [43] C. Reep and B. Benjamin, "Skill and chance in association football," *J. Royal Statistical Society*, A131, pp. 581-585.
- [44] J. Miklos-Thal and H. Ullrich, "Effort Incentives in Nomination Contests: Evidence from Professional Soccer," ZEW - Centre for European Economic Research Discussion Paper No. 09-027, 2011, 40 pages. Available at SSRN: <http://ssrn.com/abstract=1431910>
- [45] AirSafe.com, 'Plane Crashes and Other Significant Airline Safety Events by Airline.' Data available at: <http://www.airsafe.com/airline-.htm>
- [46] E-M. Hubbard, C.E. Siemieniuch, M.A. Sinclair and A. Hodgson, "Working towards a holistic organizational systems model," in *Proc. IEEE 5th International Conference on System of Systems Engineering (SoSE)*, Loughborough, 22-24 June.
- [47] Burke, C.S., Hess, K.P., Priest, H.A., Rosen, M., Salas, E., Paley, M. and Riedel, S., "Facilitating leadership in a global community: A training tool for multicultural team leaders," in *Proc. Interservice/Industry Training, Simulation & Education Conference*, 2005.
- [48] Williams, K., "Effective leadership for multicultural teams," in *Effective Multicultural Teams: Theory and Practice*, C.B. Halverson & S.A. Tirmizi, Eds., Berlin: Springer Verlag GmbH, 2008, pp. 135-172.
- [49] G.H. Hofstede, B. Neuijen, D.D. Ohayv and G. Sanders, "Measuring organizational culture: A qualitative and quantitative study across twenty cases," *Administrative Science Quarterly*, vol. 35, 1990, pp. 286-316.

Allan Hodgson obtained a B.Sc. in aeronautical engineering in 1972 and an M.Sc. in production systems in 1976. He is currently pursuing a Ph.D. in the School of Electronic, Electrical and Systems Engineering at Loughborough University, United Kingdom. His current research interests center on the effects of culture on the performance of teams. His past research interests include technology road mapping, next generation manufacturing, systems integration, modeling and simulation and production planning & control. He has worked as a lecturer and principal investigator for eighteen years and as a research associate for nine years. Prior to these activities he worked in industry as an aeronautical engineer, industrial engineer and systems analyst.

Ella-Mae Hubbard obtained an M.Eng. in systems engineering from Loughborough University in 2005. From 2005 to 2008, she worked as a research associate with the Department of Human Sciences at Loughborough University on the Knowledge and Information Management – Through Life Grand Challenge. Alongside this post, she also completed her Ph.D., investigating the configuration of decision-making systems. In 2008, she joined Loughborough University's School of Electronic, Electrical and Systems Engineering as a lecturer in Systems Engineering. Her research focuses on organizational systems, decision-making, accident investigation and the role of humans in technical systems in general. She also has pedagogical research interests in the methods of teaching and training systems engineering and associated disciplines.

Carys E. Siemieniuch obtained a B.A. in French studies from Manchester in 1974, an M.Sc. in information technology in 1987 and a Ph.D. in organizational systems design in 2005 both from Loughborough University, United Kingdom. As a principal investigator/co-investigator on a range of Engineering and Physical Science Research Council, European Union and Ministry of Defence/industry funded projects, she has developed new understandings about: the management, capture and utilization of tacit knowledge; allocation of function and systems design; impact of cultural factors on system autonomy levels; enterprise system modeling; human and organizational performance; and emergent system behaviors. She is currently a senior lecturer in systems engineering in the School of Electronic, Electrical and Systems Engineering at Loughborough University and has worked as a systems ergonomist for over 20 years in the manufacturing and aerospace domains (civilian and defense).