INTERNATIONAL DESIGN CONFERENCE - DESIGN 2008
Dubrovnik - Croatia, May 19 - 22, 2008.

DESIGN 2008

EMOTIONAL ALIGNMENT IN TEAMS: HOW EMOTIONS SUPPORT THE DESIGN PROCESS

R.J. de Boer and P. Badke-Schaub

Keywords: teams, emotions, performance, team mental models

1. Introduction

The design and engineering of all but the simplest of products is a team effort. Increasingly, the social interaction of the team members in the multidisciplinary design process has been a subject of scientific interest. It is generally accepted within the scientific community (if not always by the designers themselves) that emotions, arising from any interaction within teams, significantly impact (design) team performance. We propose as central theme of this paper that design team performance is affected primarily by a simultaneous occurrence of emotion in individual team members. That is, a design team will perform better (all other things being equal) if the emotional arousal of one team member is transferred to the other team members, for instance through heated debate. We have defined the term Emotional Alignment to describe the state of simultaneous emotional arousal in a team.

To support this thesis, we first discuss evidence from design literature and literature case studies. Thereafter, we demonstrate the likelihood of such a relation through recent exploratory research. We have measured emotional arousal through heart beat measurements while conducting the well-known NASA moon landing management case. Using different engineering and student teams as subjects, we found that high simultaneous arousal of the team members is correlated to better team performance in the case. Finally, we propose a theoretical framework to explain these findings, which combines the cognitive aspects of the shared mental model with the emotional characteristics of the group process. This framework is based on the Affect Theory of Social Exchange [Lawler, 2006], and Frijda's Laws of Emotion [2006], as well as contemporary descriptions of shared mental models.

This research will add to the current knowledge on design methodology and can facilitate the research into how team members co-operate. From a pragmatic viewpoint, these insights do not directly facilitate better designs or more effective teamwork, at least not until we can identify ways to intervene in the emotional state of team members. That then of course must be the focus of future work.

In the remaining part of this introduction we will expand on the necessity of alignment in teams, first cognitively, and then emotionally.

1.1 Cognitive alignment

The foundation of our argumentation lies in the fact that team members need to achieve (cognitive) alignment during the course of the design project. This of particular significance to our initial area of interest: design teams occupied in designing and engineering hi-tech products. These teams are characterized by three traits that elevate the significance of team (cognitive) alignment and differentiate them from other ("lower-tech") design teams. Firstly, multiple disciplines are represented on the team, each requiring in-depth knowledge and understanding such that no individual team member will oversee the whole design space under consideration. Members are rarely interchangeable. Therefore, the team members will be challenged to develop overlap and congruency with each other's mental models, and the strength of a single, complete "Team Mental Model" will be limited in comparison with lower-tech cases. Secondly, the team's goals are specified by specific requirements, and budget and timing constraints. These goals are clear only at a high level of abstraction and generally need further elaboration and entwinement into the mental model before they can de directly applied to the work at hand. Thirdly the goals (requirements and constraints) are generally challenging to the point of impossibility, at least without relaxation of some requirements, or budget or time constraints, during the course of the project. It is the team's responsibility to propose which requirements to relax, requiring further alignment of their mental models. This of course may seem surprising at first read, but can be explained from both a customer orientation and team management perspective given the intrinsic uncertainty associated with all design work. To compensate, there is usually a difference between internal (for the design team) and external (committed to the customer) ambition levels. In summary therefore, cognitive alignment within a design team is significant for team performance in our area of interest, but challenging.

1.2 Emotional alignment

Communication between team members is essential to enable the cognitive alignment of the mental models of the team members. These interactions include relational or emotional dimensions (often subliminal), which nevertheless lead to emotional responses within individual team members. We propose that the quality and extent of the shared mental model (directly related to team performance) improves if the group process leads to simultaneous (aligned) emotional arousal in individual team members. Note that implicit in the hypothesis is that the type of emotion (positive or negative; pleasure or pain) is not expected to be relevant. We anticipate that if team members, actively involved in the design task at hand, are aligned in positive emotions, they are supporting each other in pursuing the steps under consideration. If the emotions are aligned but generally negative, the team will be actively involved in searching alternative routes in answer to the challenges that evidently have been identified. Both paths are generally constructive towards furthering the design and therefore correlate with better design performance. If the emotions are mixed – that is, some team members feel elated and others are worried or disappointed – then an effective team will undergo a meta-discussion about the design and team process (rather than the work at hand), resulting in alignment of emotions on the one hand and eliminating the road blocks on the other. A non-effective team will not be able to align, and will therefore show idiosyncratic emotional response. Non-effective teams are also those where a significant number (or all) of the members are emotionally detached from the task at hand, related to a rather flat and asynchronous bodily response.

2. Evidence from design literature and literature case studies

Authors have found it challenging to integrate emotions into a coherent design methodology. Bucciarelli [1994] states (p. 159) that "the (design) process is necessarily social and requires participants to negotiate their differences and construct meaning through direct, and preferably face-to-face, exchange". He argues (p. 113) that the "multifaceted, or multi-masked, quality of design" is not reflected in the design process as it is depicted in many texts. More recently Buijs [2003] shows two separate models: a cognitive "concrete detailed model" (circular but sequential), and a non-cognitive, abstract model without given sequence. The first (an adaptation of a more traditional linear model) does not include any direct reference to social interactions, although every second step is an evaluation. The latter model comprises four activities grouped around a heart shape, which stands for "leadership, culture, emotion, motivation, risk-taking and passion".

In this chapter, we will first expand on Reflective Practice [Schön 1983] and show how elements hereof are actually very similar to emotional mechanisms. We argue that the description of Reflective Practice in teams is akin to the identification of Emotional Alignment. We will then go on to reproduce a number of documented cases of emotional (non-) alignment and its effects on design team performance.

2.1 Reflective Practice

The theory of Reflective Practice suggests that surprises precede a step forward in design work. Schön's description of surprise [1983, p. 68] is: "In each instance, the practitioner allows himself to experience surprise, puzzlement, or confusion in a situation he finds uncertain or unique. [As a consequence, RJdB] he reflects on the phenomena before him, and on the prior understandings which have been implicit in his behaviour. He carries out an experiment which serves to generate both a new understanding of the phenomena and a change in the situation." These characteristics of surprise – the interruption and urgency in an unsure situation, the associated feelings and the tendency to act - echo the definition of emotions by Frijda [2007]. This author defines emotions as: "awareness of some mode of action readiness of a passive and action-control-demanding nature, involving readiness to change or maintain relationships with the environment (or intentional objects generally); which action readiness is experienced as motivated or caused by situations appraised as relevant, urgent and meaningful with respect to ways of dealing with it; which situations are felt to affect the subject, and affect him bodily." In the context of a designer we can describe emotions as: a sense of wanting to take action that imposes itself and interrupts current activities to such a degree that it is accompanied (actually: preceded) by a variety of physiological changes, triggered by either a match or a mismatch between concerns and the perceived situation (for instance newly available information) that is of immediate significance to the designer. In summary, there seems to be a large commonality between Schön's description of surprise and Frijda's definition of emotions.

Schön's Reflective Practice has been shown to be of relevance in actual design work. Valkenburg [2000] studied the application in design teams. She finds evidence that correlates design team performance with the amount of Reflective Practice that is observed, although the sample size is very small (N = 2 for two different experimental set-ups). Both Valkenburg [p. 34 – 35, 215 – 219] and Schön [1987, p. 28 – 31] stress the importance of surprises to initiate reflection and enable the advancement of design work. However, in her case study summaries surprises are not reported; possibly because the associated behaviour is difficult to identify and code in video observation and protocol analysis. Nevertheless, she does identify (p. 135) that for the winning team "there is a moment (…) where a surprise, noticed and picked up by the whole team, has a major influence on the course of the project". In contrast, the losing team spends a lot of time discussing their approach to the problem in an unaligned fashion, with many interruptions and deviations from the chosen path.

We suggest that this supports the importance of emotions in design work. This need not be surprising. Frijda [2007] explains that emotions are functional at the level of immediate involuntary action readiness, often targeted at inter-personal relations; "the primary function of which appears to be to influence the behaviour of others". This evidently should support the development, alignment, and maintenance of congruent (cognitive) mental models throughout the design project. Retrospectively, similar simultaneous emotions within a team should then point to the growing achievement of a congruent (cognitive) team mental model.

2.2 Case studies

Kleinsmann [2006] studied the multi-disciplinary design process in a number of real-life situations, focusing on the collaboration between the actors. Particularly her second case of the design for the technical systems of a railway tunnel (analyzed through direct observation) generated a number of examples of aligned and unaligned teamwork. For instance (p. 167 – 170) she literally reports the conversation between two Control Engineers and an Escape Door Engineer. They discuss the different failure modes and associated hazard categories without being aligned on terms and meanings, while (as it seems from the transcription) being emotionally detached from each other. At the end of the conversation there is no shared understanding and the Control Engineers are asked to redo their work. We suggest that despite the rational challenges in this particular instance as extensively reported by the author (p. 170 – 179), there is also a contributing factor in the sense of emotional misalignment. Nowhere in the transcription is there evidence that these actors are bonded by a mutual cause, feel inspired by each other, or sense significant emotions (either positive or negative).

Wickelgren [2005] extensively studied the design team responsible for the development of the Volvo V70 and the S60 at Volvo Car Corporation, Sweden, from 1998 to 2001 in direct and video observation. His main objective was to identify emotions in the weekly routine of the project team (to support his thesis that emotions facilitate the creation of emotionally charged products). His report covers a large number of emotion-laden team sessions, many of which we consider representative for any team which designs hi-tech products in a multi-disciplinary setting under time and budget constraints (not just "emotionally charged products"). Positive discussions with significant progress are often labelled as "high energy meetings". In particular excerpt five (p. 278 – 284, on the amount of back tilt of the extra seat in the cargo area of the V70 station car) shows a high level of aligned emotion within the team, leading to a fruitful discussion and a unanimous decision on how to continue. In contrast, excerpt six (p. 286 – 290, covering a request to list the functionality that has been omitted from the new car in favour of safety) emits a lukewarm enthusiasm for the proposed action, and in the end the proposal is "taken out of the meeting".

Bucciarelli [1994] extensively describes engineers at work in an endeavour to show that designing is a social process. He reproduces a number of interactions which illustrate the effect emotions can have in the outcome of design decisions. In one example (p. 151), he describes a meeting in the early stages of the design process where the project leader introduces a new methodology to the team, aimed at weighing different design options without a full analysis. It is a high energy meeting with much participation and debate, but the conclusions are quite ambiguous and the team leader later refers to it as the "disaster meeting". But actually, the meeting is seen by the author as "not a failure but as a first engagement on the road to the design of a fix (…) – albeit a rough and tense first step". At the next meeting, which was much calmer, ample progress was made based on the foundations of understanding that were laid in the earlier meeting.

In a second example, the author (p. 179) replays a four-actor conference in the company president's office to decide on an expansion of the design with a third "precollimator", at a cost (of course) but leading to enhanced image capability. The meeting turns into a set of two dialogues, one discussing the added functionality of the system (president and project scientist), and the other on the cost aspects (chief engineer and project manager). In the end, both dialogues reached a similar conclusion (to add the extra unit) which therefore determined the consensus decision. From the report it is clear that both pairs of actors were emotionally aligned during the debate, whereas there was little alignment across the pairs. The author suggests that the "trade-off (…) was weakly constructed. (…) The design decision in this instance is best seen as an overlay of different interests, rather than a synthesis". One can only speculate on the outcome of the meeting had the two pairs not been in agreement.

In a final example (p. 192), the software engineer enters the office of the team leader the week before the prototype is to be shipped, stating that the software requires a run time of over two minutes compared to the 30 seconds that was specified and agreed. Naturally, the team leader is very worried and different options are ventilated. But basically, the software engineer has already decided to continue his work throughout the weekend, and all he is asking for (and getting) is emotional support that properly rewards this sacrifice. What is important in this example is that the Emotional Alignment that is demonstrated is directly linked to a clearly superior design (a run time of 20 seconds (!) rather than over 2 minutes).

From the above it follows that while there has been little direct attention for the relationship between emotions and team performance in engineering literature, many authors have reported examples of emotional alignment "in the passing". We will now in the next section introduce a methodology for identifying emotional alignment, and correlating that to team performance.

3. Results from Exploratory research

In this chapter we introduce exploratory research that has been carried out by the authors at the Delft University of Technology and at a company for aeronautical structures. The objective of these experiments was to determine the feasibility of identifying synchronous emotional arousal in subjects involved in a team task with the chosen test set-up. As will be explained below, it seems as if emotional alignment can indeed be identified with the proposed set-up and a relationship with team performance established.

3.1 Experimental method

The team task in these preliminary experiments is the well-known NASA moon landing case [NASA], which is often used to show the superiority of team collaboration versus an individual effort. Although this is not a design exercise, its value lies in the quantitative performance valuation that it allows, and its independence of team member capability and experience levels (although care must be taken to ensure that subjects are not familiar with the case). The exercise starts with individual problem solving, allowing us to baseline both the physiological state as well as actor performance. Thereafter the subjects are asked to solve the same case in small groups, which generally leads to a better performance than the individual scores. One response is requested per team so members will need to discuss their views and agree on the answers.

The score on the case is defined as an improvement from the average of the initial individual scores to the final (unanimous) team score after discussions. The scores themselves are calculated by taking the difference in ranking for the 15 items in comparison to NASA experts (as given in the case) – lower is better. In formulas:

$$\text{Team Improvement Score} = \overline{\text{Individual Scores}} - \text{Team Score} \tag{1a}$$

$$\text{Score} = \sum \text{abs}(\text{item rank}_{\text{subject}} - \text{item rank}_{\text{NASA}}) \tag{1b}$$

The physiological reaction of the actors is monitored by a commercially available wireless heart rate receiver/transmitter worn on a belt around the chest. These heart rate monitors are commonly used during physical exercising. Note that this generation of heart rate receivers is extremely accurate and measures the so called R-R interval. Every interval is recorded. Although putting on the belt may be awkward, once on the belt is comfortable and unobtrusive enough. Heartbeat measurements have been chosen as the indication of autonomic response because heart rate variation is well correlated to emotional arousal, either upward or downwards as the case may be. Performance scoring for the case study is calculated by comparing subject answers against the expert rankings as agreed among NASA scientists. Team performance is calculated as the improvement from average initial individual scores. Scores can easily be compared between teams or with earlier results as documented in the literature.

Based on evidence that emotional states are subject to thresholds [Lewis 2005, Frijda 2007], we have differentiated between physiological states if the subject's heart rate exceeds a certain value. We have defined the subject to be aroused if either the condition according to equations 2a or 2b is met, where $HR_{t,i}$ is the Heart Rate of subject i at time t, $\overline{HR_i}$ is the average of the heart rate of the subject over the monitoring period, and $\sigma_{HR,i}$ is the standard deviation of the heart rate of the subject over the monitoring period.

$$HR_{t,i} > \overline{HR_i} + \sigma_{HR,i} \tag{2a}$$

$$HR_{t,i} < \overline{HR_i} - \sigma_{HR,i} \tag{2b}$$

The emotional arousal in a team at time t is defined as follows:

$$EA_t = \frac{\sum_{i=1}^{n} a_{t,i}}{n} \tag{3}$$

Where EA_t is presented in a percentage between 0 and 100%, n is the number of team members, and $a_{t,i}$ is a Boolean variable with value 1 or 0 indicating whether the subject i is aroused at time t, as defined by Eq. (4):

$$a_{t,i} = [(HR_{t,i} > \overline{HR_i} + \sigma_{HR,i}) \; OR \; (HR_{t,i} < \overline{HR_i} - \sigma_{HR,i})] \tag{4}$$

3.2. Results from preliminary experiments

The preliminary experiments have been carried out with more than 30 subjects. Team size varied from 4 to 6 subjects. The subjects are second and third year engineering students at the Delft University of Technology, as well as junior engineers at Stork Fokker AESP. The results for two of these experiments over the experiment time (only the team work phase) are shown in Fig. 1. Here we can see the variation of the Emotional Arousal of the teams over the course of the experiment. Note that team 1 is in general more Emotionally Aroused (average Emotional Arousal, $\overline{EA}$ = 50%) than is team 2 ($\overline{EA}$ = 37%). The scores on the moon landing case reflect these levels of arousals, where team 1 scored an improvement in the case (average individual score versus team score, as discussed above) of 19 and team 2 reduced their performance by 11 points. In the direct observation, these differences can be explained. Team 1 demonstrated more intensive discussions, and involvement of more team members in these discussions, than did team 2.

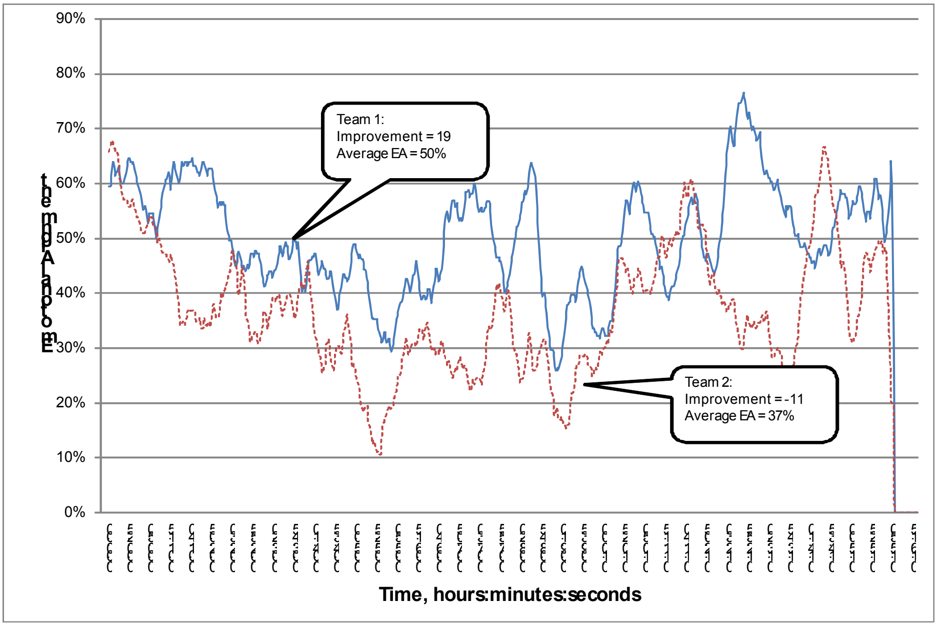

Figure 1. Emotional Alignment over the course of the experiment

Over the course of more experiments, these results were repeated. Figure 2 shows the relationship between the performance on the Moon Landing case, and the average Emotional Alignment for the five teams researched so far. The weak but positive correlation identified in this set-up can be fortified by further detailing Emotional Alignment; in particular the role of third and fourth team members above a dyad that is active in the team activity seems to improve team performance. This needs to be further investigated. Additionally, the physiological measurements will be correlated to actual activities and voice transcripts with the aid of video cameras.

4. Theoretical framework

The results of the experimental research support a theoretical framework that combines cognitive and non-cognitive elements, and identifies emotional arousal as correlated to the creation of a shared (team) mental model. This model is based on the definition of emotion as an autonomic response that arouses, focuses attention, generates affect, and creates a readiness for action; and is preceded by an appraisal of events that infringe on concerns of the individual [Lewis 2005, Frijda 2007].

The Affect Theory of Social Exchange [Lawler 2006] dictates that repetitive exchanges lead to positive emotions in the actors, such that they demonstrate staying behaviour, contributing and gift-giving. This implies an urge to remain in communication and to collaborate, in general making possible disparities in the mental models apparent to the actors. The positive emotions generated by the social aspects of the exchange are then in conflict with the negative emotions associated with the mismatch in cognitions. There is a strong desire to reduce the emotional tension. Emotional contagion, where actors infect each other with similar emotions, will further enhance the emotional tension [Barsade 2002]. It is the emotional force that generates more intensive discussions (allowing the improvement and convergence of the mental models of the actors). In our experiment, we measure these emotional processes more directly (though autonomic arousal) than is possible through visual observation, whereby the behaviour that a subject shows may be moderated or subdued through regulation processes. The suggested framework forecasts that actors with widely varying mental models that are able to bridge their differences perform better than either teams with little cognitive disparity, or teams with large diversity but with no inclination to converge. This is in line with results of recent research on conflict in design teams [Badke-Schaub et al 2007].

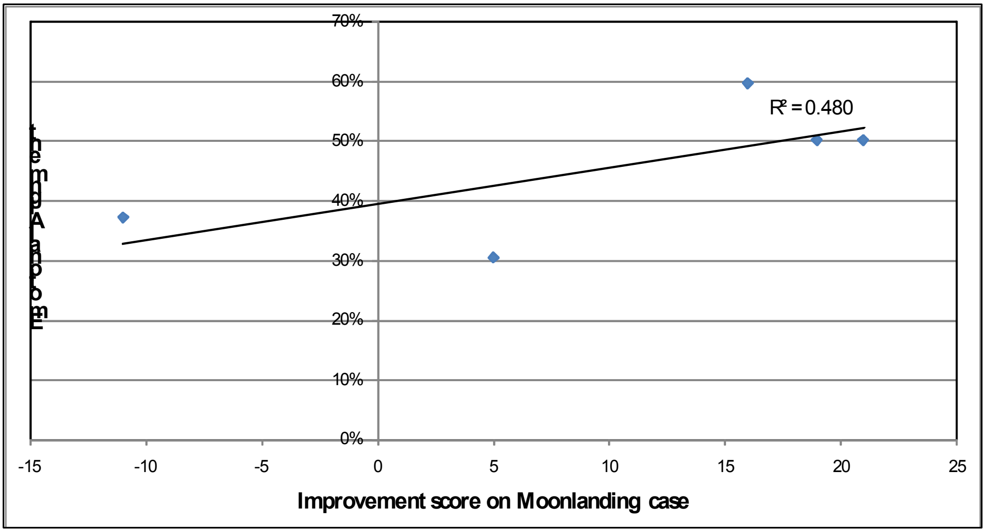

Figure 2. Relationship between team performance and Emotional Alignment

5. Conclusions and Future work

In this paper we have provided evidence to suggest a direct and significant link between the cognitive development of shared mental models, and the emotional alignment of the team (defined as the correlation between team members of emotion-induced physiological reactions). We obviously do not suggest that Emotional Alignment replaces capabilities, experience and such; rather that it has been overlooked as a symptom of (in)effective team work in design. We have referenced design literature showing examples of emotional (dis-)alignment that support our thesis. We propose that the emotional link can be monitored through the use of a heart beat monitoring device, and show how preliminary experiments support our suggestions. We have developed a theoretical framework that can help to explain this phenomenon. We believe these results to be particularly relevant to the furthering of the knowledge of the design process and how teams work together to create, maintain and develop shared cognitions, necessary to effectively design hi-tech systems. Further, we believe that we may develop over time a useful tool to actually support design teams in practice to reflect on their communication and collaboration effectiveness.

References

Badke-Schaub, P., Goldschmidt, G., Meijer, M., "Cognitive Conflict in Design Teams: Competing or Collaborating?", Proceedings of the International Conference on Engineering Design, Paris, 2007.

Barsade, S.G., "The Ripple Effect, Emotional Contagion and Its Influence on Group Behavior", Administrative Science Quarterly, Vol. 47, pages 644-675, 2002.

Bucciarelli, L.L., "Designing Engineers", The MIT press, Cambridge, Massachusetts, 1994.

Buijs, J.A., "Modelling Product Innovation Processes, from Linear Logic to Circular Chaos", Creativity and Innovation Management, Vol. 12, No. 2, June 2003, pp. 76 – 93.

Frijda, N.H., "The Laws of Emotion", Lawrence Erlbaum Associates, Inc., Mahwah, NJ, 2007.

Kleinsmann, M.S.,"Understanding Collaborative Design", PhD dissertation, School of Industrial Design Engineering, Delft University of Technology, 2006.

Lawler, E.J., "The Affect Theory of Social Exchange", Contemporary Social Psychological Theories, edited by P.J. Burke, Stanford University Press, Stanford, California, 2006

Lewis, M.D., "Bridging emotion theory and neurobiology through dynamic systems modeling", Behavioral and Brain Sciences, Vol. 28, pp. 169 – 245, 2005.

NASA. Survivor on the moon. [cited; Available from: http://www.nasaexplores.com.

Schön, D.A., "The Reflective Practitioner", Basic Books, New York, 1983.

Valkenburg, A.C. (2000), "The Reflective Practice in product design teams", PhD dissertation, School of Industrial Design Engineering, Delft University of Technology, 2000.

Wickelgren, M. (2005), "Engineering Emotion", PhD dissertation; School of Business, Economics and Law; Göteborg University, 2005.

Corresponding Author:
Ir. Robert J. de Boer
PhD Candidate
Delft University of Technology, Department of Product Innovation and Management
p/a Brouwerij 5, 3703 CH Zeist, The Netherlands
Tel.: +31 30 2981950 / +31 6200 17882
Email: r.j.deboer@tudelft.nl
URL: http://www.io.tudelft.nl