# 1 INTRODUCTION

Problem exploration and problem framing are important stages in design, allowing teams to investigate underlying needs, define characteristics, and establish problem boundaries (Dorst & Cross, 2001; Volkema, 1983). Strategies for understanding a problem space include using "alternative perspectives" and reframing problems based on stakeholder and context research (Lee et al., 2020). Alternative perspectives have the potential to shift designers' views about core elements of a problem and can redirect them towards new and more impactful problems and solutions (Hey et al., 2008).

An important way for design teams to understand and incorporate stakeholder perspectives is called "perspective taking" — a designer's ability to adopt a stakeholder's point of view (Surma-aho & Hölttä-Otto, 2022). For the purpose of this work, stakeholder perspective taking is defined as a practice in which a designer takes on the point of view of a stakeholder or group of stakeholders. In this practice, the designer uses perspectives gathered from stakeholders to put themselves in the context and mindset of those being considered in order to represent the stakeholder's needs throughout problem exploration and framing. Perspective taking supports knowledge boundary spanning within diverse teams (Hoever et al., 2012) and is important for problem framing and the generation of useful ideas (Grant and Berry, 2011). However, not all designers (broadly defined as anyone involved in design work) may engage in perspective taking to the same degree. Technical disciplines and settings where designers rely heavily on deep technical expertise may present barriers to perspective taking.

Prior research has identified some conditions that encouraged engineering students to take on stakeholder perspectives, such as guiding students through role-playing exercises and challenging cases (Hess et al., 2017). However, it is unclear what conditions may or may not encourage experienced professional engineers to adopt stakeholder perspectives. This study examines when and to what extent professional engineers engage in perspective taking as they frame design problems in a highly technical organization, the United States National Aeronautics and Space Administration (NASA).

# 2 BACKGROUND

## 2.1 Problem Exploration and Framing

One way of viewing design is as reflective actions through which problems are framed and solution space is constructed by designers (Schön, 1983). Problem framing and reframing works to find the "problem behind the problem" and create a "fresh perspective" that allows new possibilities for design (Dorst, 2015; Paton & Dorst, 2011). Scholars have identified rhetorical schemes by which design teams shift frames (Stumpf & McDonnell, 2002), iterative stages of reframing, the importance of surprises in inciting reframing (Stompff, et al., 2016), and the role of designer's emotion (Ge et al., 2021). Prior work suggests that designers better develop solutions when they have thoroughly explored different aspects of a design situation, including various stakeholder needs and constraints (Cross, 2007; Fricke, 1999).

## 2.2 Stakeholder Perspective Taking

Stakeholder perspective taking can help designers to incorporate broad points of view while exploring design problems (Surma-aho & Hölttä-Otto, 2022). Prior work has identified three dimensions involved in stakeholder perspective taking, including gathering data to form perspectives, scoping and making sense of perspectives, and applying the perspectives during design (Surma-aho et al., 2022). Human-centered design (HCD) scholarship offers many strategies for incorporating stakeholders' needs and perspectives. This body of work recommends that designers gain empathy for stakeholders (Kouprie & Visser, 2009). However, recent studies have highlighted the limitations of empathic understanding in design, such as difficulties in fully taking on the emotions, beliefs, and mental models of others (Heylighen & Dong, 2019; Surma-aho & Hölttä-Otto 2022).

## 2.3 Engineers Taking Stakeholder Perspectives

Scholars have examined how students take on stakeholder perspectives in engineering design projects (Surma-aho & Hölttä-Otto, 2022; Hess et al., 2017). While much literature exists on perspective taking generally, and some exists on stakeholder perspective taking among designers and engineering students,

little work has examined stakeholder perspective taking among professional engineers with deep expertise in a technical discipline (e.g., aerodynamics, propulsion). For the purposes of this paper, we refer to professional engineers as engineers who have deep expertise in a specific engineering discipline. The skill of perspective taking may be particularly important when professional engineers approach complex societal challenges (e.g., food insecurity) because applying a technological solution to such challenges can have major negative unintended impacts (e.g., modern irrigation systems causing major crop losses in Balinese rice terraces; Lansing, et al. 2017). This makes stakeholder perspectives essential in elucidating and attempting to avoid such unintended consequences. Additionally, if engineers are not involved in stakeholder engagements, stakeholder's points of views can get lost or disregarded during solution development. In this study, we focus on understanding perspective taking among professional engineers in early-stage design. However, we posit that the skill of stakeholder perspective taking will remain critical throughout the design process, particularly when addressing societal challenges.

### 2.4 Research Questions

This study examines perspective taking in a professional engineering design setting. We address the following research questions:

1. How did professional engineers adopt stakeholder perspectives during human-centered design?
2. What conditions encouraged or hindered the adoption of stakeholder perspectives during a human-centered design project (particular design facilitation, design activities, etc.)?

## 3 METHODS

We conducted an ethnographic field study of an early-stage design team within the Convergent Aeronautics Solutions (CAS) project at NASA. This occurred during a five-day design project in October 2022 which was informed by previous work conducted by the authors in CAS between March and June 2022. During the field study, we collected interviews, observations, and archival documents of design meetings to better understand the extent and conditions under which team members adopted stakeholder perspectives during their design process.

### 3.1 Field Site: NASA CAS Design Sprint

The CAS project at NASA aims to accelerate the future of aviation by developing transformative solutions to complex societal challenges like fighting wildfires and enabling access to healthcare. In spring 2022, CAS launched a 12-week early-stage design effort aimed at framing the problem of "increasing capabilities for underutilized U.S. communities through aviation connectivity." The team included four NASA engineers, a CAS lead, two contracted designers, and an intern. During the effort, the NASA engineers interviewed a wide range of rural community members across the United States. Engaging in this effort revealed several challenges in executing early-stage design work within the constraints and time pressure of a real-world environment, including collecting rich qualitative data, developing a shared understanding of stakeholder needs, and adopting and advocating for stakeholder perspectives. These challenges presented opportunities for short, iterative explorations of ways that an HCD process could be tailored for effective problem framing in a highly technical professional setting.

Informed by the 12-week design effort, we conducted a five-day design project in fall 2022 to examine one of the aforementioned challenges: how and when professional engineers adopt stakeholder perspectives. This involved a geographically distributed team of five NASA engineers, a CAS lead, and two contracted designers. The five NASA engineers included both men and women with a variety of technical aviation backgrounds (e.g., air traffic management, avionics). Four were senior engineers and one was an early-career engineer. Three had previous HCD experience gained during the 12-week design effort. The contracted designers had a background in innovation and design strategy for tackling complex problems with experience across various industries. The CAS lead and the contracted designers worked together on design strategy and facilitation of the 5-day design project which focused on weather tolerant operations for advanced air mobility. During the project, the team reviewed transcripts and audio recordings of previously conducted qualitative interviews with stakeholders of the challenge (e.g., advanced air mobility vehicle operators and data managers). Then the team analyzed these interviews, identified stakeholder needs, and formulated problem framings for subsequent development.

### 3.2 Data Collection

Data were collected in the form of qualitative interviews, observations, written reflections, and project documentation on an online whiteboard. Informed consent was obtained for all research participants. We video recorded and transcribed three roughly four-hour design team meetings. Additionally, facilitators recorded daily reflections, and a dedicated observer took fieldnotes throughout the project. Documentation from eight design activities were preserved in the online whiteboard. The primary data source for data analysis was the video recorded design team meetings. Contextual data came from team interviews, written and audio recorded reflections, field notes, and whiteboard work. To protect privacy, research participants are referred to by letters (Participants A-E).

### 3.3 Data Analysis

We qualitatively coded design team meeting transcripts from the final three days of the five-day project. While there exist many theories of behavior change within the social sciences (Davis et al., 2014), we chose the Theoretical Domains Framework (TDF) from Michie, et al. because it provides a framework for explaining conditions that encourage new behaviors and skills within a particular situation (Michie et al., 2005; Atkins we al., 2017). We sought to conduct an initial analysis of behavior change within a team of professional engineers as they were encouraged to use a human-centered design approach.

Our codebook included a combination of theoretical codes based on TDF and inductive codes that emerged from our data. We took our unit of analysis to be any instance of team discussion in which a participant made a decision or judgement and provided justification for it. We began by identifying these instances and then conducted an iterative thematic analysis to identify patterns across them. One team member initially coded the transcripts for these instances. All codes were discussed by 2-3 research team members using a negotiated agreement approach to decide if the participants' judgement or information came from their personal knowledge or from a stakeholder perspective. We then placed each identified instance along a one-dimensional spectrum with "fully taking stakeholder's point-of-view" and "fully taking designer's point-of-view" on opposite ends. The instances within the middle of the spectrum were reviewed and clustered to identify patterns which ultimately led to the emergence of two additional categories: “Interpreting stakeholder point-of-view using the designer's point-of-view" and “Implanting stakeholder point-of-view into the designer's point-of-view." We coded the contexts around all instances and developed a set of codes for "encouraging" and "hindering" conditions under which shifts in level of perspective taking appeared to occur. We then synthesized patterns within each condition category.

### 3.4 Addressing Validity

Given that our study is ethnographic and embedded within a single organization, we strove for internal not external validity. Future research may examine the generalizability of our findings by testing them across multiple organizations and contexts. To establish internal validity, we followed recommended practices for analyzing qualitative data (Miles & Huberman, 1994), including establishing strong theoretical foundations from the relevant literatures, triangulating using multiple data sources (observations, recordings, etc.), and debating results among a team of multiple researchers.

## 4 FINDINGS

We present our findings in four sections starting with the spectrum of stakeholder perspective taking that we observed among professional engineers. Then we describe how individual designer's perspective taking changed with time and the conditions that appeared to encourage or hinder perspective taking.

### 4.1 A Spectrum of Perspective Taking During Problem Framing Deliberations

Our analysis of problem framing deliberations identified 52 instances of participants justifying their understanding of the design situation. We categorized these along a spectrum with four categories, from highest to lowest level of stakeholder perspective taking: (1) Fully taking the stakeholder’s point of view (POV) (17 instances), (2) Interpreting the stakeholder’s POV using the designer’s POV (13 instances), (3) Implanting the stakeholder’s POV into the designer’s POV (9 instances), and (4) Fully taking the designer’s own POV (13 instances). Definitions of each level are presented in Figure 1.

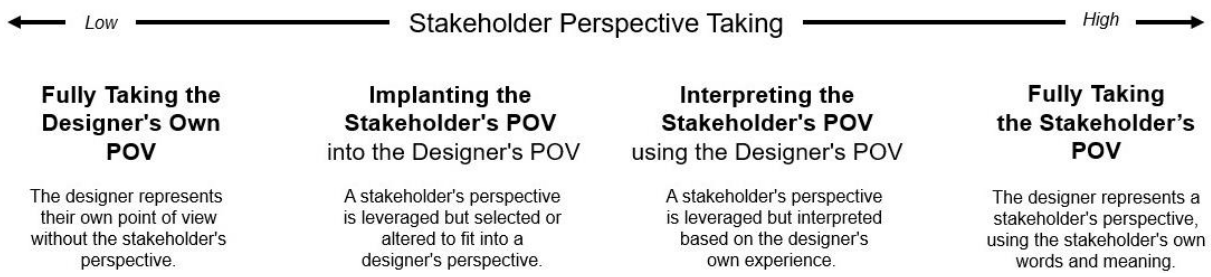


*Figure 1. A spectrum of stakeholder perspective taking*

*Designers fully took a stakeholder's POV* when they represented the stakeholder's perspective using the stakeholder's own words and meanings during problem framing deliberations. For example, during a discussion of stakeholders' needs, a designer shared that, "they [the stakeholders] want to be a player, they want a seat at the table, and they want to be acknowledged." In another example, a designer said, "I don't remember hearing any of the interviewees specifically talk about interoperability." In both cases, designers actively examined or questioned and attempted to voice the stakeholders' expressed POVs.

Moving leftward in the perspective taking spectrum, *designers interpreted a stakeholder's POV* when they leveraged a stakeholder's perspective but interpreted it based on their own experience. For example, one designer shared that, "there was talk about lack of, while they didn't call it a lack of information, they kept referring to information available at other airports […] and you can make the leap to that." Here, the stakeholder did not directly express a lack of information, but the designer identified an insight about lack of information based on the stakeholder's words and the designer's interpretation of them.

Moving further to the left, *designers implanted a stakeholder's POV* when they leveraged a stakeholder's perspective but altered or selected it specifically because it fit well within their own POV. To illustrate, a designer shared that, "if the respondents are complaining about regulations, such as they are now, the only way to get beyond this is through data acquisition to prove a test case or proof of concept in order to alter the regulation […]. But that's my perspective because I work so closely with NASA." Here, the designer leveraged a stakeholder's POV (complaints about regulations) and inserted it into an expression of their own POV (that data acquisition is the only way to get beyond complaints about regulations).

Finally, the lowest level of stakeholder perspective taking is when *designers fully took their own POV*. This occurred when designers shared their own ideas without connection to stakeholder's expressed POVs. For example, during a discussion of challenges faced by stakeholders, a designer shared that, "I'm involved in some standards development, and I like to say that standards help interoperability." Here the designer provided their own perspective–that "standards help interoperability"–without connection to stakeholder's perspectives on this topic.

Each of these four levels of stakeholder perspective taking were observed across our data set, however, individual designer's perspective taking varied along the spectrum (Figure 2). Participants C and D (who had some prior HCD experience) were skewed to the higher end of the spectrum when compared with Participants A and B (who had no prior HCD experience). Participant E was absent from this part of our dataset and could not be included in this analysis.

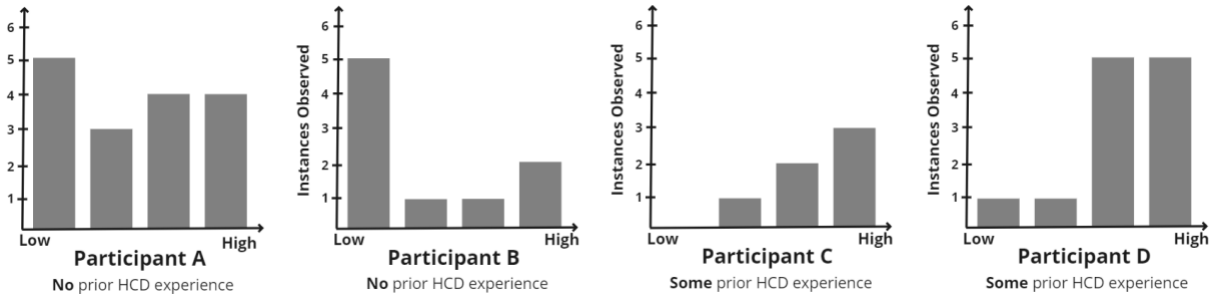


*Figure 2. Individual participant stakeholder perspective taking during problem framing*

### 4.2 Stakeholder Perspective Taking During Presentations: Internal vs External

Participants presented their identified stakeholders' needs on two occasions, once internally to their team and once externally to leadership. The first presentation involved structured storytelling during which participants were invited to select and present one theme (need statements and related stakeholder quotes) to their teammates. On the next day, participants were each invited to select one theme to present to leadership as a priority for NASA. In both cases, participants had access to the same stakeholder data, storytelling templates, etc. and made their selections independently. In the presentations to leadership, two of four participants shifted toward lower-level stakeholder perspective taking, moving away from interpreting or implanting stakeholder perspectives to relying exclusively on their own perspectives (Figure 3). Participant B was absent from the final day and could not be included in this analysis.

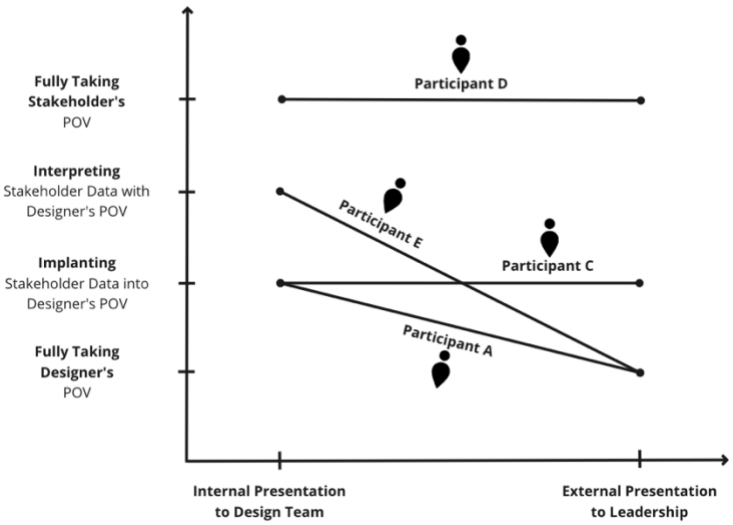


*Figure 3. Observed changes in participants' stakeholder perspective taking when they presented internally to design teammates versus externally to project leadership*

### 4.3 Conditions that Encouraged Stakeholder Perspective Taking

We observed conditions that appeared to encourage stakeholder perspective taking with participants relying less on their own expertise and experiences. These included participants' familiarity with HCD, templates that focused attention on stakeholders, and facilitator framing and prompting (Table 2).

*Table 2. Conditions that encouraged stakeholder perspective taking*

| Encouraging Conditions | Evidence from Data |
|---|---|
| Familiarity with human-centred design | Participants with some prior HCD experience (Participants C and D) exhibited higher levels of perspective taking compared to participants with no prior HCD experience (Participants A and B) (Figure 2) |
| Activity templates that focus attention on stakeholders | Templated activities that focused participants' attention on stakeholder POVs (Figure 4) supported higher perspective taking |
| Facilitator framing / prompting | Facilitator prompts during problem framing sessions: "*Remember, just keep it connected to our data*."; "*Did we hear from the interviewees about [that]?*"; "*I would encourage you to double check to see that we do have evidence to back that up*." |

Participant familiarity with HCD appeared to encourage stakeholder perspective taking. Throughout the project, Participants C and D were observed wrestling with their understanding when their own perspectives did not match those of stakeholders. For example, during a team discussion, Participant C said: "*I won't say anything about my viewpoint because I know we are supposed to focus on stakeholders' views. […] I keep finding myself going down the path of what I think would be a good solution or a good thought and then kicking my, you know, hitting myself in the head: 'No, you gotta think in their terms, what they think, or what they expressed that they want.*" In another instance, a facilitator asked Participant D for more insight into an idea that s/he had just triangulated across three stakeholder interview transcripts. Participant D paused and reviewed the transcripts for evidence before answering.

Similarly, unfamiliarity with HCD and related methods appeared to be associated with lower-level perspective taking and concerns with the process and related data. For example, participant A reflected, "*Well, there's a there's a subjective aspect of this, right? Isn't there a tendency to grab a quote and then infer within that quote your own personal bias?*" Participants with more HCD experience were generally observed to have higher trust in the process and higher trust in stakeholder perspectives. However, this was not universal. One experienced participant shared a sense of unease with using stakeholder data, calling their problem statements "squishy" and added, "*You know, if I'm going to nail something to the wall. I like a nice firm 2-by-4 that holds its shape. But nailing jello, man, that's a tough thing to do.*"

Beyond HCD experience, facilitator framing and prompting (as described in Table 2) and activity templates that focused attention on stakeholder POVs appeared to support perspective taking. As an example, the storytelling activity template asked for evidence of stakeholder needs (see Figure 4) which appeared to encourage stakeholder perspective taking in the subsequent discussion.

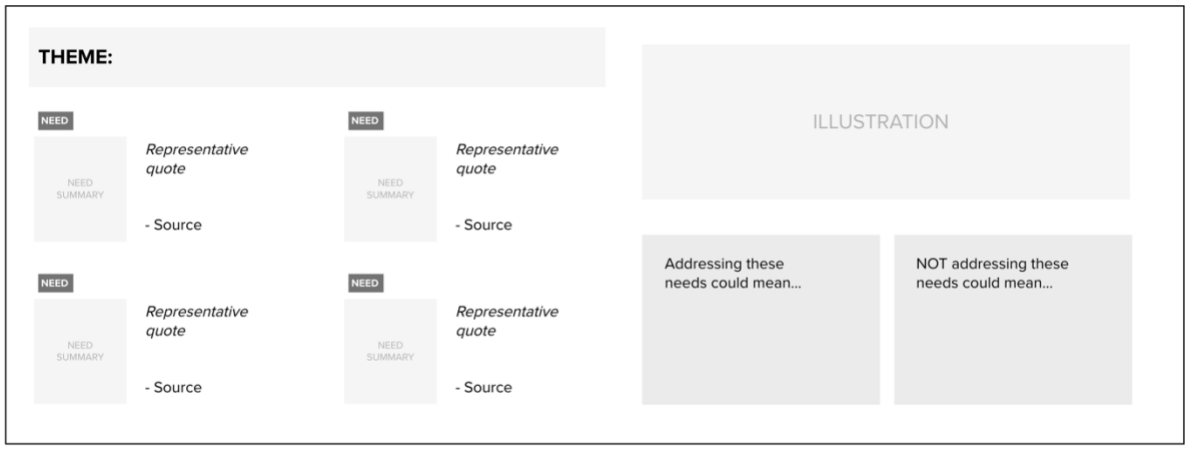


*Figure 4. Template example from a storytelling activity*

### 4.4 Conditions that Hindered Stakeholder Perspective Taking

We also identified four conditions that appeared to hinder stakeholder perspective taking: three individual attributes and one environmental condition. Individual attributes that appeared to hinder perspective taking were: (i) personal connection and memories, (ii) existing knowledge and expertise, and (iii) claimed identities and values. In 29 instances, participants referenced their own memories, previous knowledge, or claimed identities in lieu of stakeholder data. An environmental condition that appeared to hinder perspective taking was the pressure to prioritize findings and present to leadership, as discussed in Section 4.2. Table 3 summarizes conditions that seemed to hinder perspective taking.

*Table 3. Conditions that hinder stakeholder perspective taking*

| Hindering Conditions | Evidence from Data |
|---|---|
| Personal connection and memories | "*I remember standing in line at an at an airline kiosk…*" - Participant D<br>"*But that's my perspective because I work so closely with NASA.*" - Participant D |
| Existing knowledge and expertise | "*[From my] understanding of how the entirety of the industry is going to be moving forward.*" - Participant D<br>"*It's not NASA's sole job to come up with all the various use cases for something, right?*" - Participant B<br>"*I'm involved in some standard development and I like to say…"* - Participant B |
| Claimed identities & values | "*Well, since I am an engineer, I'm gonna go with 'data'.*" - Participant B |
| Pressure to present to leadership | Observed changes in participants' perspective taking when they presented externally to project leadership vs. to teammates (Figure 3). |

# 5 DISCUSSION

Our findings present a spectrum of stakeholder perspective taking and use a behavioral change framework to begin identifying conditions that encourage or hinder professional engineers' adoption of stakeholder perspectives. These findings have implications for design research and practice.

## 5.1 Implications for Design Research

We present a preliminary spectrum of stakeholder perspective taking in design during problem framing deliberations (Figure 1). This spectrum suggests that there are more than just two extremes when it comes to perspective taking in design. Design research generally advocates for fully taking the stakeholder's POV. However, problem framing is a dance of balancing perspectives, and there may be moments when designers should hold their own perspectives in favor of stakeholders'. Our findings suggest that experienced engineers adopt many different POVs during problem framing and that stakeholder perspective taking can be encouraged or discouraged by the conditions described in our analysis. Further research is needed to understand when designers should fully apply a stakeholder perspective versus their own perspective (or some level in between) during a design process.

We postulate that a similar analysis of student engineers would likely result in different levels along the spectrum. For example, students may be less likely to implant stakeholder perspectives into their own expertise and points of view, since these may be more limited than those of professional engineers. Prior studies have investigated perspective-taking skill development among engineering students (Hess et al., 2019; Surma-aho et al., 2022) but have yet to identify levels of perspective taking that can inform where students are as they develop perspective taking skills. Future work is needed to examine the differences between how experienced and novice engineers learn and apply stakeholder perspectives during design processes. Such work could better inform design pedagogy and post-graduation training opportunities.

This work also highlights the value of examining how professional engineers learn and adopt design skills since this may be different than how students adopt such skills. As engineering organizations look to adopt more sustainable and equitable design practices, there are opportunities to investigate facilitation tools and methods that support professional engineers to learn and practice skills like perspective taking. Our results suggest initial conditions that encourage versus discourage engineers from adopting a stakeholder's perspective during problem framing. There are also opportunities to investigate how and when engineers consider stakeholder perspectives during the later stages of design, such as concept generation, selection, and detailed design. For example, what enables specific POVs to be carried throughout a design process? How often do engineers need to re-engage with stakeholders to further understand their POVs as the problem is framed and reframed during solution development? How does perspective taking change when engineers co-design with stakeholders using co-constructive methods? Answering such questions can inform how engineering teams conduct their design practices and provide recommendations for practicing engineers to ultimately improve their design skills and outcomes.

## 5.2 Implications for Design Practice

In addition to design research implications, our findings suggest practical guidance for organizations that aim to increase stakeholder perspective taking among their design teams.

### *5.2.1 Encouraging stakeholder perspective taking*

Conditions such as strong facilitation, prompting, and templatized activity structures may support a team of professional engineers to engage in stakeholder perspective taking. However, this study reveals that additional considerations may be involved when conducting HCD work within highly technical organizations, such as the nearness of an engineer's personal experience to the design challenge or the pressure to prioritize topics independent of stakeholder data when presenting to leadership or speaking for one's organization. If such considerations are ignored, a team's ability to take on stakeholder perspectives may be at risk and become reliant on strong facilitation and structures. This has important implications for how much voice stakeholders end up having in the decisions of design teams.

If stakeholder perspectives are deemed as critical input to design decision-making, leaders responsible for the structure of the design work and formation of teams should consider the interaction of these conditions and invest accordingly to produce a desirable result. Our findings suggest that professional engineers, even highly technical single-discipline engineers, can fully take on stakeholders' perspectives. However, this is a skill that can take practice to hone and can be supported by strong facilitation and guardrails that encourage skill building while counteracting organizational pressures. Otherwise, such pressures can lead to strong swings in designers' perspective taking. Building perspective taking skill can be done through repeated exposure, coaching on mindset and biases, and facilitation techniques such as a personal experience "parking lot" that helps designers to mentally separate their own memories and existing knowledge from what they have heard from stakeholders.

#### *5.2.2 Interaction of conditions*

We did not use a research design that allowed for assessment of causal or interaction effects. However, based on our findings, we would hypothesize that increasing the encouraging conditions, such familiarity with HCD or strong facilitation (Table 2), would increase stakeholder perspective taking whereas increasing the hindering conditions, such as expertise in a technical area relevant to the problem or pressure to present to leadership (Table 3), would influence engineers to rely more heavily on their own perspectives. These factors interact. As an example, based on our experience we would expect increased structure and facilitation to have a greater effect on novice teams than highly experienced teams. As another example, in the face of increased organizational pressure, a lack of structure or facilitation may lead to decreased stakeholder perspective taking as observed in the activities described in section 4.2. We hypothesize that the effects of these conditions manifest in both the magnitude and permanence of the behavior change. Additional exploration of this interplay is outlined in future work.

## 6 CONCLUSIONS & FUTURE WORK

Our study identifies a preliminary spectrum of perspective taking among professional engineers in a highly technical organization. This spectrum includes four categories, from highest to lowest level of stakeholder perspective taking: (1) Fully taking the stakeholder’s POV, (2) Interpreting the stakeholder’s POV using the designer’s POV, (3) Implanting the stakeholder’s POV into the designer’s POV, and (4) Fully taking the designer’s own POV. We observed conditions that encouraged and hindered perspective taking and propose a nuanced interplay of these conditions during design work. We suggest that perspective taking is a critical skill to better understand, especially for organizations like NASA whose professionals are working on societal problems with real-world, large scale implications.

This study investigated a limited case study of five participants engaging in one design activity. We were unable to report specific details about our participants, including specific technical experiences and social identities. Future work should explore the roles that different identities, such as race, gender, and technical backgrounds, play in stakeholder perspective taking, including the identities of the stakeholders engaged and alignment between stakeholder's and designer's identities.

This study also highlights an example of how a functional design project can serve as a tactical experiment that helps an organization to rapidly learn and iterate on its internal design processes. It has illustrated the practicality and applicability of rapid experiments as a technique to implement new design methods in large organizations.

We see opportunities for future work to deepen the field's understanding of stakeholder perspective taking within professional engineering design teams. Future studies may consider frameworks that consider the magnitude and duration of behavior change toward stakeholder perspective taking. This could incorporate multiple aspects of participant behavior, such as a baseline, distance moved from the individual's baseline, and the duration of the individual's sustained behavior change. Each participant may have a baseline amount in which they represent a stakeholder perspective when all other conditions are absent. When encouraging or hindering conditions are present, individuals may move from their natural baseline thus increasing or decreasing their representation of the stakeholder perspective. Facilitation strength, structure, training, and salience of external pressures appear to be levers by which organizations can encourage stakeholder perspective taking within their design teams.

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