PHENOMENOLOGY OF MICRO AIR VEHICLE RESEARCH

By

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To my parents, Marco and Irene Rodriguez. Without their support and encouragement it would have never been possible.

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I wrote this phenomenology with three audiences in mind: my professors in the College of Journalism, my interviewees in the College of Mechanical and Aerospace Engineering, and citizens of the United States of America. First and foremost, however, it was a personal journey. Micro Air Vehicle phenomenology was a cathartic process of coming to terms with scientists by understanding them, to reconcile past aspirations to be a scientist as I move forward professionally. I am attempting to see technological research vicariously through the eyes of engineers, to recover some of the inspiration I once felt, as David Bowie (1995) sings:

> It's difficult you see
> To give up baby
> To leave a job
> When you know the money's from day to day
> All the majesty of a city landscape
> All the soaring days of our lives
> All the concrete dreams in my mind's eye
> All the joy I see thru these architect's eyes

Second, as noted by the engineers I interviewed, there is a tendency in the field of journalism and communications to assume that engineering is too complex. My study represents an attempt to elucidate barriers to communication between scientists and journalists, and thereby open discursive channels. It is an attempt to forge discourse between two disparate fields. My goal is to generate mutual interest between the two disciplines. However, I am also writing my study for the engineers who graciously

participated in my project. I hope that they will gain from it an insight into their own research, in terms of laboratory dynamics, design process, and ethical considerations.

Finally, my study attempts to illuminate motivations underlying an important new technology with revolutionary implications for surveillance. Micro Air Vehicle phenomenology is an attempt to see the technology through the eyes of the architects, from inception to fruition, without bias. It is an attempt to develop empathy with the engineers to see clearly their intentions for future applications. My study is a meditation on the ethics, politics, inspiration, and motivations that underlie an emergent technology, and the way that technology impacts the "human sensorium," or the Life World of the individual.

Micro Air Vehicle technology has relevance to the War on Terror. Its underpinnings relate to how we legislate Fourth Amendment rights. My study has deeper significance as a warning to Americans to carefully consider the implications of military technology, and the regulation of that technology by Congress. *Washington Post* correspondent Robert O'Harrow noted that there was increased cooperation between government and industry in the area of surveillance since September 11, 2001. A government that trivializes its citizens may see those citizens abandon free thought in favor of social aggregates as the axis shifts from democracy to mass democracy, from governance to surveillance.

As Sandra Chance, Director of the Brechner Center for Freedom of Information at UF, once observed in a personal conversation, Americans must decide whether we are willing to sacrifice freedoms to feel safe.

San Jose, Costa Rica, 2006

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This thesis presents the lived experiences of engineers at the University of Florida who are working on an emergent surveillance technology, Micro Air Vehicles (MAVs). Micro Air Vehicles are six-inch and smaller airplanes originally conceived by the U.S. military as a form of battlefield reconnaissance. However, their applications are only limited by imagination.

The central methodological tool for my study is phenomenology. Phenomenology was born in the early twentieth century out of the writings of Edmund Husserl (1859-1938). It has since been adopted as a form of qualitative inquiry that focuses on the lived experience of interview subjects so as to form a composite, essential description of their common experiences of a phenomenon. The key aspect of phenomenology that distinguishes it from other forms of qualitative inquiry is its emphasis on describing the phenomenon so as to remove initial researcher bias. This is known as bracketing, or epoche.

My study focused on four major points: generating an essential description, explaning why research participants chose to study MAVs, describing the MAV as the product of negotiation among members of the laboratories, and the ways in which creativity manifested in the design process. Overall, the MAV researchers were found to place great emphasis on pushing boundaries of science for the sake of research itself. Researchers were very competitive, but also placed a great deal of emphasis on socialization in the design process, including qualitative analysis. However, they showed reluctance to discuss ethical issues of military funding however.

Finally, creativity manifested as the product of group interaction, actively seeking out areas of personal inspiration, and through changing design parameters. Future qualitative studies should focus on issues that remained unspoken my study, such as the absence of women in the laboratory, or the relevance of ethics and politics to the engineering process.

CHAPTER 1
INTRODUCTION

Purpose and Importance of the Study

My study is a phenomenology of Micro Air Vehicle research at the University of Florida. Micro Air Vehicles (MAVs) are small airplanes with wingspans of six-inches or less that originated in a military initiative to produce a new generation of surveillance equipment in the late 1990s. Micro Air Vehicles have various applications falling under the rubric of surveillance, including battlefield and urban reconnaissance, search and rescue, law enforcement, and wildlife analysis. The military anticipates MAVs will have a revolutionary impact on surveillance. Micro Air Vehicles portend a reorganization of the way wars are fought and the ways in which Americans define privacy.

The purpose of my study is to better understand the experience of engineers of the emergent technology known as MAV research, as a means to come to terms with the philosophies and tacit assumptions underlying the technology, precisely because the MAVs will have such a profound impact on privacy and future wars. The methodological tool for cultivating this understanding of MAV engineers is phenomenology. Phenomenology is a form of qualitative inquiry that emphasizes the elimination of bias so as to ascertain essential structures of lived experience. Phenomenology is a method for developing understanding without preconception.

The end product of a phenomenology is an essential description of the phenomenon, which is a composite of all the experiences of the individual participants in

the study. The essential description reveals key structures of experience. Generation of this essential description is the focus of my study.

As a corollary, my study gathers evidence for the MAV as "research object." The term "research object" comes from the writings of Louis Bucciarelli (2002), who suggests that technology is a cultural artifact that is the product of negotiation among laboratory members. The purpose of comparing the MAV researchers' descriptions of the MAV to Bucciarelli's theory of "research object" is to verify the existence of negotiation in laboratory research. My study also compares creative models in the MAV lab to current models of creativity (Boden, 1994; Dunbar, 1997).

Thus, my study grapples with the co-researchers' personal philosophies that underlie MAV technology and that could potentially impact civil liberties and warfare. Phenomenology of MAV researchers reinforces models of qualitative analysis and creativity in engineering research. Studying the emergence of MAVs sheds light on how engineers negotiate a new technology. Qualitative research of MAV researchers stimulates self-reflection in the engineering community about the social and creative processes of conducting novel technological research.

Science writers who cover cutting-edge science will benefit from a deeper understanding with MAV researchers as a result of reading about lived experiences of engineers, and particularly reflection on what it takes to communicate research to friends, family, lay people, and the press. Phenomenology of the experience of MAV research will contribute to a more robust understanding of communicative processes between scientists and journalists, as well as between scientists and the general public.

About Phenomenology

Phenomenology is not frequently used in the field of communications and warrants a brief introductory explanation. A philosophical movement that stems from the twentieth century work of the philosopher Edmund Husserl (Moustakas, 1994), phenomenology is also a qualitative method that seeks to remove bias from the perspective of the researcher and distill the essential nature of a phenomenon (Creswell, 1998). The process of removing bias is known as bracketing, or epoche.

Phenomenology is particularly useful in psychology and other health-related fields because it can be used to discern the essential nature of abstract concepts. For example, in his explication of phenomenology Moustakas (1994) cites a variety of phenomenologies describing depression and abuse, the experience of triple bypass surgery, or the nature of Jung's shadow archetype. Other forms of phenomenology do exist. Sokolowski (2000) provides a very accessible introduction to phenomenology. He generates phenomenology of common objects, such as a tree and a box. There is a precedent for applying phenomenology to a specific form of technology. For example, Nunberg (2005) conducted phenomenology of the Internet. My study follows the prescriptions set forth by Creswell (1998) and Moustakas (1994) regarding phenomenology, with reference to Sokolowski (2000).

Phenomenology has various forms. Moustakas' definition of transcendental phenomenology serves as the methodological basis for my study. Transcendental phenomenology differs from other forms of phenomenology in its emphasis on bracketing (or epoche). Moustakas (1994) elaborates on transcendental phenomenology, tracing it back to Husserl, and distinguishing it as having more emphasis on bracketing than mere psychological phenomenology. The transcendental aspect of phenomenology

refers to Heidegger's (1975) distinction between being and human beings. Transcendental phenomenology also breaks down mental perceptions into two aspects; objects and perceptions. (Page 39 gives a more complete discussion of transcendental phenomenology.)

Phenomenology requires full description of the phenomenon from the perspective of the researcher. The researcher engages in an initial description of the phenomenon from his or her own perspective, and then envisions possible interpretations of that description as a means to identify preconceptions (Creswell, 1998). After removing these preconceptions, the researcher looks for emerging elements in the interviews that are essential to the description of the phenomenon. The researcher attempts to equalize these elements by not favoring any particular perspective on the phenomenon, and by devoting just as much attention to important words and phrases as to entire paragraphs and pages. These elements are clustered into non-repeating, non-overlapping categories of like themes, and these themes are used in turn to generate individual descriptions that focus on the facets of experience: objects, events, and people. These are textures of experience. These descriptions are then interpreted to uncover the implicit meanings of the lived experiences, the researchers' perceptions and intentions toward their experience. These are the structures of experience. The final step is to synthesize these individual textural-structural descriptions into one essential description of the phenomenon.

According to Mitcham (2005), particularly in North America, little had been written about philosophy of technology. Mitcham does, however, identify some European philosophers who grapple with the slippery subject of technological ethics, and their analysis takes the form of phenomenology. Idhe (1990) conducted phenomenology

of technology as it relates to every day experiences and sensory perceptions of the individual. Casey and Embree (1990) compiled a number of articles similarly concerned with phenomenology of the experiences of modern humans vis-à-vis technology.

Numerous qualitative studies of engineering research exist in the literature, but many of these are ethnographies geared toward improving performance of engineering teams. Existing phenomenologies of technology tend to adopt a large-scale perspective. Phenomenologists have traditionally been mistrustful of the idea of performing phenomenology on the level of an individual technology. This causes the researcher to get too caught up in the details of an individual project, and miss the overarching themes that characterize a larger phenomenon (Mitcham, 2005).

The present phenomenology focuses on understanding researchers' lived experience with reference to a specific kind of engineering research, the MAV. Conducting phenomenology of MAV research presents a novel opportunity to bring the macro-level tool of phenomenology to bear at the microcosm to understand the philosophies and experiences underlying a cutting-edge technology. Rather than focusing on generalization, as phenomenology traditionally does, this case-level application of phenomenology yields insights that are highly contextualized, and therefore rich in detail. This is useful specifically as a meditation on experiences and implicit philosophies of MAV researchers, and what their designs suggest for surveillance applications. The results also provide insights into the role of qualitative analysis and creativity in the engineering laboratory and the process of communicating research to peers and the media.

Statement of the Problem

Much has been written about MAV research in the popular press. Articles about MAVs have appeared in numerous national and international publications over the past decade. Nothing has been written in the academic literature about these machines from a qualitative standpoint. As Mitcham (2005) has noted qualitative considerations of technology are not as prevalent in America as in Europe. However, a number of articles have been published concerning the relevance of ethnography to the engineering laboratory (Jagodzinski, Reid, Culverhouse, Parsons and Phillips, 2000; Ball and Ormerod, 2000; Button, 2000; Lloyd, 2000). Bucciarelli (1994, 2002) wrote about the research object as the product of a collective process. Baird, Moore and Jagodzinski (2000), described ethnography of engineers at Rolls Royce Aerospace, suggesting a model for team interaction and the value of such a study in understanding the pressures and constraints upon engineers. Engineering was also considered in terms of design philosophy (Galle, 2002), and artistic merit (Eder, 1995).

All of the above studies emphasized the value of understanding engineering from a constructivist perspective that examines the importance of discourse in an otherwise quantitative field. However, not only were most of these studies produced outside the United States, but they emphasized the facility of understanding such interactions from a business perspective, for example, to increase efficiency of workforce. The phenomenologies of Idhe (1990) and Casey and Embree (1990), on the other hand, explored macro-scale aspects of technology, and broached ethical concerns. These phenomenologies were not concerned with business applications of qualitative studies, but rather take a more philosophical approach to technology. My study bridges these two perspectives to make practical observations about laboratory research, while also saying

something larger about ethical and philosophical dimensions of researchers' attitudes toward technology.

A critical approach to technology stands at odds with basic tenets of phenomenological inquiry and bracketing (Moustakas, 1994). One of the major obstacles to conducting a phenomenology of MAV research is the need to eliminate initial preconceptions of the research to see it clearly through the eyes of the engineers. It is also necessary to eliminate bias so as to be receptive to co-researchers and form relationships characterized by empathy, or I-Thou relationships (Buber, 1970). Another objective of phenomenology is to appease the loneliness of individual experience by generating understanding. Understanding involves establishing a relationship with another person, through painstaking transcription, naïve and general description, and *I-Thou* interactions. By doing this, we move beyond initial perceptions, using bracketing to relinquish preconceptions going into the interview (Moustakas, 1994).

Research Focus

Meloy (1994) noted that it is difficult to provide research questions for a qualitative study a priori because the nature of the research requires immersion in a subject to understand a problem. It is only possible to articulate such questions at the end of a study. As such, my study offers a research focus in place of research questions. The focus of my study is to understand the experience of MAV researchers from the perspective of engineers. Following the steps in phenomenology, this involves first discovering individual textural meanings of the experience of MAV researchers. These are translated into individual structures that contextualize the experience of MAV researchers. Finally, the composite textural-structural description of the experience of MAV researchers is given—the essential description.

My study also comments on three other points as corollaries to generating the essential description of the experience of MAV researchers. First, why did the researchers choose to study this particular form of technology? Secondly, what does the MAV represent from the perspective of the engineers as an artifact of discursive negotiation, in the sense of Bucciarelli (2002) and his notion of "research object"? Finally, what are the major creative processes at work in the MAV laboratory?

Definition of Terms

As previously stated, because phenomenology is not often used in the field of communications, it is appropriate to rigorously define its terms. The following is a list of terms specifically used in phenomenology. Many of the following definitions are based on descriptions found in Moustakas (1994) and Creswell (1997):

Bracketing (Epoche). Husserl's essential component of phenomenological inquiry, which begins the process. The researcher engages in bracketing as an exercise to strip away preconceptions and biases about the phenomenon, to be receptive to all possible interpretations. This involves recognizing and reigning in one's own biases (Moustakas, 1994; Creswell, 1998).

Co-researcher. According to Moustakas (1994), the interviewee/subject should be regarded as a co-researcher. The process of phenomenology is largely concerned with cultivating a rapport with interviewees. The title co-researcher signifies the constructivist stance adopted by phenomenological researchers.

Constructivism. Paradigmatic approach to research that comes after post-positivist and critical theory. Constructivism stresses the subjective nature of reality that is constantly being negotiated through the process of communication and the importance of text as an epistemological tool (Anderson and Baym, 2004).

Essence. The essential nature of a phenomenon revealed by phenomenological inquiry. The essence emerges in the synthesis of the individual textural and structural descriptions. Also known as essential or invariant structure (Moustakas, 1994; Creswell, 1998).

Ethnography. Qualitative method that is the primary tool of anthropologists. Ethnography is the study of culture from the inside, whether this is a tribal people or an engineering laboratory. It is therefore ecological in the sense that it emphasizes immersion in a culture to study that culture from within (Bucciarelli, 1994). Painstaking insider observation and reporting are key to ethnography (Creswell, 1998).

Horizonalization. Horizonalization is the process of assigning emergent aspects of the phenomenon equal value. In phenomenological reduction, this takes place after bracketing. The researcher decides that certain elements called horizons are essential to a description of the phenomenon, and considers each one with equal weight. The researcher makes a list of these horizons. Horizons are textural meanings of the phenomenon, and are constants of the experience, or invariant constituents. There are an infinite number of horizons, so the researcher must be judicious in deciding upon those that are essential to the description of the phenomenon (Moustakas, 1994; Creswell, 1998).

Imaginative Variation. In phenomenological reduction, after the researcher has engaged in naïve description of the phenomenon, he explores all possible interpretations of the description by varying the meaning and considering the phenomenon from a multiplicity of perspectives. Once this is completed, the process of bracketing is complete, and the researcher is ready to proceed to horizonalization of the interview data. Imaginative Variation can incorporate music, poetry, and art (Moustakas, 1994).

Intersubjectivity. Husserl's term to explain the way reality is socially constructed. Reality is composed of a multiplicity of perspectives. Before a researcher can understand another's perspective, he must first understand his own through the process of bracketing preconceptions (Moustakas, 1994; Sokolowski, 2000).

Life World (*Lebenswelt*). The personal, internal world of the individual as opposed to the systems of scientific inquiry, such as physics and mathematics. The Life World describes how the individual interacts with reality on a daily basis (Sokolowski, 2000).

Naïve Description. Naïve description is the initial attempt on the part of the researcher to describe his or her experience of the phenomenon, to enumerate essential perceptions that may or may not be accurate. It is the first step in bracketing (Creswell, 1998). A naïve textural description describes the essential facets of a phenomenon. Imaginative Variation of these naïve textures describes personal feelings or impressions of the phenomenon, that is, any intentions that the researcher holds toward the textural aspects. Naïve description can be a way to infuse the essential description with the researcher's perception of the phenomenon. In the Van Kaam method of phenomenological reduction, however, naïve description is mainly a tool for bracketing (Moustakas, 1994).

Noema and Noesis. Intentionality suggests a fundamental relationship between subject and object. This is not to say, however, from the perspective of phenomenology, that there are not universal characteristics of a phenomenon. Indeed, it is the end goal of phenomenology to produce such an essential description. Moustakas (1994) makes a distinction between an object and one's perception of an object. This schism gives rise to the concepts of noema and noesis, which are aspects of a person's mental perception of a

phenomenon. The noema is the object-correlate. It is the mental perception that points to the essential nature of a phenomenon, but that is more descriptive and perceptive. "[N]oema is that which is experienced, the what of experience." Noema is associated with textural description (Moustakas, 1994; pp. 69-79). Noesis is the subject-correlate, that is, the mental perception that points to the essential nature of the phenomenon, but that is more concerned with judgment. "[N]oesis is the way in which the what is experienced." Noesis is associated with structural description (Moustakas, 1994; pp. 69-79). The point is that noema and noesis are dual aspects of the individual's mental perception of a phenomenon.

Research Object. Bucciarelli's (2002) term for the end product of engineering design. The term emphasizes the discursive nature of engineering design, which gives rise to technological forms as ethnographic artifacts.

Structural Description. Structural description is linked to noesis (Moustakas, 1994). Structural description is how the phenomenon is experienced, and "involves conscious acts of thinking and judging, imagining and recollecting" (p. 79). Moustakas suggests three main classes of mental phenomena that further clarify the distinction between textural and structural aspects of perception. First, there are presentations, and these are the noema, or textures. In reality, new phenomena (objects, people, impressions) are constantly presenting themselves, emerging from and vanishing back into the background. There is not necessarily any significant intention toward these objects. They are merely presenting. But there are also perceptions and emotions toward some of them. These perceptions and emotions are the noesis, or structures. Structural description, then, describes the aspects of experience that do not merely emerge and fade

as horizons, but register a higher level of intentionality, of correspondence between subject and object. This manifests as a perception or emotion, a consistent conceptual thread between that spans textures. The structures can be either conscious or unconscious.

Synthesis. Synthesis of textural and structural descriptions to reveal the essential experience of the phenomenon, or its essence (Moustakas, 1994).

Textural Description. Textural description elaborates the phenomenon's physical and/or primary features (as in the case of something intangible, such as depression or love). Textural description involves the common elements of a phenomenon, yet is still subjective in nature. Textural aspects are associated with the noematic phases. The textural description represents the "what" of a phenomenon, i.e., what it is like to experience that phenomenon, the facets of the phenomenon that are presenting—the invariant horizons (Moustakas, 1994; pp. 78, 79).

Personal Interest in the Topic

My reasoning for conducting phenomenology of MAV research is first inspired by a sense of fascination regarding technology and science. At a young age television played a large role in my development. Not being a very athletic child, I more often found myself creating imaginary worlds with the other children on my street. Television science fiction programs transfixed me. Most notable among these was the long-running BBC serial *Doctor Who* (Davies, 2005), which features a time-traveling physicist alien as the protagonist.

From this, I developed an interest in the science. Taking physics in high school, I found it quite difficult, but nevertheless enrolled as an undergraduate physics major. I plodded through two years of undergraduate physics, only to abandon the effort before

enrolling in quantum mechanics. Perhaps appropriately, the most difficult class I undertook (and subsequently failed) was a course in analog electronics. My undergraduate thesis was a trilogy of science fiction stories and a brief history of the genre. I thought, if I could not do science, at least I could write about it.

Science fiction can function as a form of communicating real science to lay people, as well as raising ethical questions (Lambourne, 1999). By broaching ethical questions concerning engineering technologies, science fiction functions in the place of a tradition of philosophy of technology, which according to Mitcham (2005), is largely absent in North America. For example, O'Harrow (2005) provides a prime example of science fiction commenting on science fact when he uses *Minority Report* (Spielberg, 2002) as a touchstone for discussion of emergent surveillance technologies. As the MAVs are an emergent surveillance technology, O'Harrow's references to *Minority Report* seem appropriate.

As a result, my inspiration for conducting MAV phenomenology is two-fold. On the one hand, it stems from a fascination with science perceived through the lens of science fiction that goes back all the way to childhood. On the other, because of my recent background in science fiction, it emerges from the belief that science fiction can be used as a metaphor to discuss real science.

My initial interest in MAVs came about in the fall of 2002, while working briefly as a gardener for a UF lepidopterist. He suggested that if I had an interest in science writing, I investigate research in the UF aerospace department on small airplanes inspired by birds and insects. Because of my previous interest in search and rescue robotics, I decided to take his advice.

This interest in search and rescue robotics came about as a result of an experience I had on September 11, 2001. My international flight from London Gatwick to North Carolina made an unscheduled stop in Halifax, Nova Scotia, that morning. I thought the plane was crashing. Then the captain explained that terrorists had demolished the WTC. For the next four days, I became a first-world refugee. One of the first thoughts that came into my head after hearing what had happened was whether or not search and rescue robotics would be employed in the rescue effort. Indeed, this is what happened (Lee, 2001). Nothing could have impressed upon me more completely the urgency of developing search and rescue technology, and their potential dual role in surveillance.

Two years later, while enrolled in my first year in a journalism graduate program, I resurrected my notes on the topic and conducted a series of interviews for a short article. The next semester, while enrolled in a qualitative methods class, I incorporated my research on MAVs into an inchoate phenomenology.

After discussing the matter with my professor, I decided to expand this paper into a full-fledged thesis. Though the project unfolded over a period of two years, the initial seeds were planted almost four years ago. Even though one does not know it at the time, the mind is always gathering information, and, as with the qualitative research process, slowly, imperceptibly, formulating synergistic perceptions.

CHAPTER 2
LITERATURE REVIEW

Phenomenology, Life World and Technology

How can phenomenology be practically applied to study of technology? A number of scholars have attempted to apply phenomenology to technology, including Idhe (1990), Casey and Embree (1990) and Nunberg (2005). Also, other areas of qualitative research have been applied specifically to engineering, for example, Bucciarelli (1994; 2002) approached laboratories ethnographically. Marchessault (2005) suggested that McLuhan conducted phenomenology of modern society. For example, in his posthumously published *The Laws of Media*, McLuhan offered up the idea of the tetrad, an experimental technique for "historical and phenomenological investigation of objects, to describe forms of media" (Marchessault, p. 224).

Idhe (1990) and Casey and Embree (1990) framed their phenomenological inquiries in broad terms, taking a sweeping social perspective, specifically with reference to a term forwarded by Husserl called the Life World. Sokolowski (2000) defined the Life World as the personal, internal world of the individual as opposed to the systems of scientific inquiry, such as physics and mathematics.

Phenomenology and the Life World thus have a relationship to democracy. This is relevant because the systems of society are a kind of technology imposed on human life. In fact, as we shall see, Idhe (1990) argued that technology manifests implicitly as cultural convention. Next, we turn our attention to phenomenological considerations of

technology itself. We begin with philosophy of technology, which sometimes incorporates phenomenology.

Mitcham (2005) briefly chronicled the development of philosophy of technology, which is two-pronged. Philosophy of technology began to emerge in the late nineteenth century. American schools have largely ignored many of the continental thinkers who developed philosophy of technology. These thinkers tended to develop the idea of technology as organic, meaning technologies were seen as extensions of organs. Another school arose contemporaneously, which included a range of thinkers from Kant to Heidegger. This school came to see technology as dystopian, standing between man and God, life or organic existence. In other words, one branch of thought suggests technology issues from humans, and the other says that it mutates human nature. Such perspectives can be applied phenomenologically to MAV research by interrogating the perspectives of the engineers on the product of their research. From the perspective of the researchers, what are the primary applications of the MAVs? How do they amplify or attenuate human ability?

Mitcham also noted several problematic areas in the interaction of humans with technology. These include distribution of technological resources, alienation from labor (in the Marxian sense), and how technology is integrated into the realm of the "human sensorium" (p. 544). Another problem includes the issue of how we deal ethically with the power that technology places in our hands arises, for example, in the question of whether or not engineers are qualified to make public safety decisions. Some of these ethical considerations are crucial to understanding MAV research. The purpose of my study is to understand how technology is integrated into the researcher's perception, how

researchers regard their labor, some potential applications envisioned for MAVs, and how MAV researchers view research ethics.

Mitcham suggested that technicity underlies technology, and chronicled the evolution of the term from Aristotle through Descartes, Mill, and later Heidegger and Ellul. According to Mitcham, Heidegger viewed technology as a challenge to ontology, and as something transhuman, in that it is undergirded by the drive to advance for advancement's sake. There is only a "human veneer" (p. 574). This attitude toward technology relates directly to my study. Heidegger's transhuman view of technology for technology's sake suggests the question of the researcher's motivation to design MAVs.

Finally, Mitcham observed, "There is also a tendency for the engineering school to make alliances with the Anglo American analytic tradition of philosophy, and for the humanities school to find a convenient partner in the European phenomenological tradition" (p. 546). Furthermore, phenomenological researchers tend to shy away from viewing technology on a case by case basis, because they believe that this robs the technology of important historical and social context. This is problematic for a phenomenology of MAV research, in which the focus is on a particular form of technology. However, conducting phenomenology on a case-by-case basis has the benefit of familiarizing the researcher with the details of how new technology is negotiated. This microcosmic perspective provides more insight into the social world of the laboratory, and is not something that can be achieved through grand theory.

Idhe (1990) provided an example of a how phenomenology can be practically applied to the study of technology, albeit from a meta-perspective of society as a whole. He began with a general textural description of being awoken by an alarm clock, eating

breakfast, getting into a car, etc. After this introduction, he conducted Imaginative Variation of a hypothetical Eden where people go without technology. He noted that this could only occur in tropical regions, and that it could only have occurred before recorded history. People have always used tools (and again, he refers to the human use of tools as technics) for cooking, self-defense, etc. The closest people to these hypothetical Eden-dwellers are the modern Tasaday in the Philippines, but even they employ rudimentary technologies for cooking, clothing, etc. Even ants and primates use technology. Thus, it is as if Idhe concluded that technology and humanity are inextricably linked in a symbiosis.

Idhe also questioned how technology alters human perception of nature. He gave the example of a mountain. Prior to the nineteenth century, mountains were considered a blight, the sight of which was to be avoided. The industrial revolution changed this sensibility. Modern mountain-climbing gear is an extreme expression of this nostalgia for mountains, and has taken our ability to interact with them to an extreme.

Idhe noted the pros and cons of a face-to-face interaction with the natural world, i.e., either a relaxing soak in a hot spring, or falling from a cliff. And yet, because we interact with the world in a way that is perceptual, that is, through the senses, we may assume that this provides some kind of unadulterated communion with nature. Thus, Idhe broached the topic of the "ingrained technics of ritual," as in the case of the Egyptians, who went so far as burying people alive so that they might accompany the deceased into the underworld (pp. 16-18). Social technics may be just as influential as engineered technology in modifying human interaction with the natural world, albeit in a more insidious way. Essentially, Idhe provided an interesting model for

phenomenological reduction and Imaginative Variation, and demonstrated how culture itself can be construed as a kind of technology.

The Ego-Centric Predicament

It is worth noting an important epistemological benefit of phenomenology. Sokolowski (2000) suggested that phenomenology is a throwback to the philosophy of ancient Greece. He saw it as an alternative to postmodernism, which he regarded as the despairing notion that a thing is defined by the multiplicity of its parts, but that wholeness and truth escape us. Thus, phenomenology represents the idea that the various parts point to a consistent whole.

To Sokolowski, phenomenology represented a means to escape a problem in philosophy associated with Descartes' cogito ("I think, therefore I am.") that is traditionally called the "ego-centric predicament." As a consequence of living under a Cartesian world-view, the "intramental" world is defined in opposition to the "extramental" world (pp. 9-12). Perceptions are received through the filter of the senses, delineating between the physical world and thoughts about the physical world. Phenomenology presents a solution to this dilemma. For example, intentionality stresses a subject-object relationship. Phenomenology does not distinguish between intramental and extramental. There is not the thought and the thing—they are one and the same.

Sokolowski also pointed to the potential of phenomenology to illuminate a "publicness of mind," (pp. 11-12) as a result of the intimate connection between mind and objects. Consciousness equals consciousness of something. Because of the public nature of consciousness, it is possible to communicate about the nature of every-day objects. This also has political implications: "Phenomenology strictly addresses the epistemological aspects of modern philosophy, but that does not mean that it cannot say

something about political philosophy, since the idea that we are all beings of truth is a component of citizenship" (p. 7). There is a political dimension to this phenomenology, one that relates to the implications that the figure of the MAV holds for the future of democracy from the perspective of its creators.

Similarly to the concept of publicness of mind, Idhe (1990) suggested that phenomenology is like ecology, where we study other animals from within the ecosystem because there is no way to extricate ourselves from the web. Moustakas (1994) noted this as a common component of qualitative forms of inquiry. In his ethnography of various engineers, Bucciarelli (1994) referred to the "ecosystem" of the engineering laboratory (p. 127). It is to Bucciarelli's ethnographic approach to engineering that we now turn. His ideas are particularly relevant to the question of the MAV as "research object." First, however, we must provide context for Bucciarelli's research by rigorously defining constructivism.

Constructivism

Constructivism is key to my study in its emphasis on contextualized observations. According to Knopf (2004), Essence is something that transcends physical objects of experience. The Essence is something universal, and thus the term "objective" phenomenology (p. 40). But modern phenomenology has undergone a pragmatic shift, especially the American incarnation:

> The fruit of phenomenological research has changed from Essence to essence. That which was once thought to be a description of universal truths of experience, has evolved to become characteristics of experience that are situated within the context of the participants being studied (Crotty, 1998) or subjectivist phenomenology. In other words the aim is no longer to describe universal truths that apply to all, but rather a description of a phenomenon that is situated within the context of culture and shared experience. [Knopf, 2004; pp. 40, 41]

This interpretation applies to my study. We have already seen that applying phenomenology on a case-by-case basis to technology garners criticism from two sides. On the one hand, the American philosophical tradition has largely ignored technology. On the other, Continental phenomenologists are dubious of a study that purports to discern anything essential by studying a single technology. Nevertheless, my study aligns itself with a more practical approach. As a result, the study cannot reveal universal truths regarding the interactions of humans with technology, but rather only contextualized observations. Such observations foreshadow at an essential description of how engineers regard research, research objects, and associated creative processes.

This paradigmatic shift from "Essence to essence" should not be underestimated. In terms of explanatory power, such a transition represents not only a shift from universal truths to situated truths, but also a transition from post-positivism to constructivism. In a nutshell, there are four paradigms for scientific inquiry, three of which are still relevant (Anderson and Baym, 2004). The first, positivism, became obsolete in the late 19th century. Positivism was the ontology of natural scientists seeking an ultimate science that would explain an objective reality. Post-positivism dispensed with this notion, culminating when Thomas Kuhn (1996) published *The Structure of Scientific Revolutions*, in which he elucidated the concept of paradigm shift. Natural science could not discover an ultimate expression of reality, but through periodic upheavals, the scientific world could continually refine its worldview to more accurately approximate reality.

The critical paradigm deconstructs post-positivistism by exploring cracks, faults, and blind spots. For example, Haraway (1989, 1997) dissected military science and

genetics from a feminist perspective. Virilio (2000) and Baudrillard (1994) approached technology and media from the standpoint of technological determinism. Finally, however, constructivism suggests in our everyday interactions, we negotiate reality. In this way, constructivism escapes the paradoxical situation of critical theorists who attack authority from the privileged position of being authorities themselves. Conducting phenomenology that focuses on situated essences cannot be widely generalizable, but perhaps this scaled-down perspective actually portrays reality more accurately than a macro-scale critical approach.

Object World and Research Object

Useful concepts can be borrowed from Bucciarelli's (1994, 2002) laboratory ethnographies for the purposes of phenomenology: "object world" and "research object." While ethnography is an entirely different qualitative tradition than phenomenology, there are common elements between the two. For example, both require the majority of theoretical work to be done before conducting research. Both ethnography and phenomenology emphasize lived experience of the co-researcher, immersion in the subject, and pain-staking description (Creswell, 1998).

The concept of "object world" (Bucciarelli, 1994; p. 55) introduces some gray areas into the otherwise clear-cut process of engineering research. Bucciarelli defined the object world in various ways. For example, in the case of an engineer working on a computer model of solar cells used to convert salt to potable water in the Saudi desert, the object world consisted primarily of the hardware of the photovoltaic cells, as well as mechanical artifacts such as pumps. Yet, these artifacts were "as much the symbolic, mathematical relationships" that regulated the many factors involved in the functioning of the system, as well as the computer language that she used to write the software to

model the system (p. 63). For another engineer, the "object world" consisted of a system that was merely a blueprint and had "not yet been embodied in hardware" (p. 65).

Different engineers with different specialties (electrical, mechanical, etc.) tend to view the same research object differently. There can even be micro-discrepancies in interpretation of objects between people with the same specificity. To illustrate this subjective decision-making process on the part of the engineer, Bucciarelli noted the difficulty the U.S. has had converting to the metric system: "…the bit of time (seconds) it takes to make this simple numerical conversion is like a gap across a canyon separating two different worlds. We do not understand metric the way we know English. It is not part of our culture, our object-world heritage" (p. 78). One particularly dramatic example is the crash of NASA's Mars Orbiter (Lloyd, 1999), in which the American engineers worked in inches, but their British compatriots worked in metrics. Another example is that for an electrical engineer time scales are typically in milliseconds, but for a mechanical engineer time scales involve minutes and hours. Thus, there are different perspectives ("object worlds") that need to be reconciled in the process of design, and these are of a highly personal nature (pp. 80, 81).

One important aspect that derives from the concept of object world is the need to negotiate the terms of design from the multiple perspectives of the researchers. For example, diagrams (such as circuit diagrams) negate all but the most important components of an object, leaving room for ambiguity of interpretation, such as in the spatial construction of the final product versus the 2-D blueprint. Bucciarelli (1994) suggested how a process could be viewed as an object. A management process, for example, can be represented as a flow chart based on principles of control theory.

Bucciarelli (2002) wrote about the design object as the product of a collective process. He underscored the value of transitional artifacts in the design process—back of the envelope style diagrams that are eventually incorporated into the final design, working acronyms, and management flow charts. Each of these represented a step along the way to the final "research object" that were important subjects of discourse and negotiation in the lab (pp. 219-231). As noted above, some of these common, ephemeral elements in the process of MAV design could be elucidated through phenomenological inquiry.

Discovering the parameters that define the "object world" of MAV researchers is part of the focus of my study. What common metrics define the MAV from the perspective of the engineer? What artifacts form an ephemeral trail along the way to the finished product, such as diagrams on napkins, or working anagrams? What subjectivities require negotiation in the spatial construction of the final "research object"?

Qualitative Studies of Engineering

A brief survey of qualitative engineering studies revealed a number of perspectives, ranging from critical studies, to elite interviews, to ethnography. Stanley and Slattery's (2003) article on biracial qualitative research noted the difficulty in putting aside critical bias as researchers, a topic of particular relevance to phenomenology. The research participants in the study—all engineering students—suggested that science functions as a lingua franca that transcends gender and racial lines. However, the authors dismissed these claims, and insisted that there were undercurrents of gender and racial politics in the focus groups. The authors reject the possibility that science could be a common language that equalizes gender and racial relations.

Another problem of conducting qualitative research with scientists is the inability of lay researchers to communicate with scientists in this common language. For a non-specialist, then, developing rapport requires applying elite interview techniques. This is the case in my study. In her article on transformational elite interviews, Kezar (2003) suggested a calculated approach to interviews in which there is a perceived power relationship. She made some suggestions to de-politicize the interview, for example, recognizing the interviewee's desires to be acknowledged as a human being, and recognizing elite time constraints.

Kezar's elite interviews relate to Reed's (2001) qualitative analysis of scientists and science journalists. Reed identified several areas of friction between the spheres of science and the media, such as out-of-sync time schedules, perceived power relations, mutual ignorance of organizational constraints, and differing conceptions of audience, accessibility, and accuracy. The last one—accuracy—is particularly interesting, because science and journalism have come to represent divergent epistemologies: the relativism of the journalist, vis-à-vis the post-positivist engineer or scientist as "modest witness" to natural phenomena (Reed, 282).

The publication *Design Studies* devoted an entire issue in 2000 to ethnography of engineering laboratories. A number of these made reference to Bucciarelli's (1994) concept of the "object world." For example, Lloyd (2000) suggested that social experience in the engineering laboratory is a neglected topic. He incorporated the "object world" to explain how different teams of engineers working in a software company construct narratives to communicate with one another, and assign varying connotations to the same words. For example, the word "sufficient" has different meaning to an engineer

working in sales as opposed to a designer (pp. 369-370). Baird et al., (2000), described ethnography of engineers at Rolls Royce Aerospace. The Rolls Royce study incorporated Bucciarelli's (1994) notions of laboratory ecology. The authors focus on the lab's response to change and pressure, and creativity, among other factors.

Creativity

Various models of creativity have been proffered, and phenomenology is sometimes one approach to unmasking this mysterious concept. The philosopher Karl Popper suggested that attempting to model creativity was unimportant. Creativity occurs randomly, and the source of creativity is not as important as the discovery itself (Boden, 1994). In this sense, his "pessimistic" view of creativity was not all that different from that of Plato (p. 3).

In an essay on whether engineering is art or science, Eder (1995) noted that creativity does not simply occur, but comes about as a result of oscillations of intellectual and intuitive modes in human psychology. Boden (1994) reinforced this perspective, and suggested that there may be more to the process of creativity. For example, she cited one of the authors in her anthology, David Perkins (1994), who suggested a model of "Klondike spaces" for creativity. Scientists and artists have a "Klondike map" of "conceptual landscapes," and as a result, their creativity is not random. It is not a "eureka" situation, but rather a calculated effort to unearth discoveries (p. 7).

Boden (1994) defined creativity in terms of P-creativity and H-creativity, or psychological creativity and historical creativity. Psychological creativity involves an individual who has a type of thought that they have never personally experienced before, but that was conceived by others before. Historical creativity involves an individual having a new thought that no one has ever had before. To Boden, creativity is not just

novel combinations of previously existing ideas, e.g., merely slinging together gibberish to make new sentences. Rather, it means engendering systemic changes in a set of constraints, like Schoenberg's space of atonal music, or Lobachevsky's formulation of non-Euclidean geometry. Boden also notes that the presence of certain "transformational heuristics"—such as dropping constraints, varying variables, or considering the negative—might be required in order for young children to exhibit certain forms of creativity (pp. 86-91).

Dunbar (1997) studied how scientists think about and manifest their creativity. He followed experiments in four molecular biology laboratories, and conducted interviews with over 21 scientists, including senior scientists, grad students, and research technicians before, during, and after the research process. Contrary to the popular conception in scholarly literature on the topic of scientific creativity, Dunbar concluded that scientists infrequently make use of analogies from outside of their field to make important discoveries. Many of the analogies used by the molecular biologists were homologies between structures within the same organism or similar organisms, and thus analogies in a very specific sense of the term.

Dunbar also suggested that scientists working in laboratories were more apt to attend to inconsistent findings than participants in psychological experiments. The process of negotiating with other scientists (dubbed "distributed reasoning") allowed scientists to generate alternative hypotheses that they might not have been able to see otherwise (p. 484). Finally, Dunbar concluded that scientific reasoning is a multi-faceted process, involving "[a]nalogy, induction, deduction, causal reasoning, and distributed reasoning." Scientists had little memory of the creative process involved in discovery:

"Thus, much of the on-line cognitive processes that went into the conceptual change would have disappeared without a record if I had not taped the original meeting" (pp. 487, 488). This is significant, because it points to qualitative gray areas in the engineering research process similar to those identified by Bucciarelli (1994; 2002) in his definition of the "research object" (i.e., personal preferences of metrics, arbitrary elements left to the imagination by a circuit diagram).

The research focus concerned how creativity manifests during the design process. It may be interesting to note the role of analogy and distributed reasoning in the production of MAVs, but more importantly the degree to which MAV researchers identify these elements in their creative process. Do MAV researchers seek out the "Klondike spaces"? How much of the creative process is a team effort? What sorts of "transformational heuristics" are employed in the process of MAV design?

CHAPTER 3
METHODOLOGY

Micro Air Vehicle research portends a significant effect on the nature of warfare, as well as privacy rights in the United States. However the technology also has applications to wildlife conservation, and is intended to save lives. Phenomenology was chosen as the method of inquiry for my study due to the potentially explosive social impact of MAV technology. With its emphasis on eliminating preconceptions, phenomenology of MAV researchers' lived experience promised a more unbiased, realistic glimpse into the thought processes of the architects who design this volatile new technology, so as to more rationally discuss applications and ethical issues.

In order to talk meaningfully about phenomenology, we should take some time to define it more rigorously. I will begin with Creswell's (1998) schematic of phenomenology, included as part of his outline of five traditions in qualitative research. Creswell advances a psychological approach to phenomenology inspired by Moustakas (1994).

Phenomenology Basics

Phenomenology focuses on the meaning of lived experiences surrounding a concept or phenomenon (Creswell, 1998). Phenomenology has its roots in the philosophy of the mathematician Edmund Husserl (1859-1938), and later Heidegger, Sartre, and Merleau-Ponty. Phenomenology posits an essential, invariant structure or underlying meaning (essence), and data analysis proceeds through a methodology of reduction, using bracketing (or epoche). Through phenomenological reduction,

phenomenology is meant to return scientific inquiry to its origins in “natural science,” that is, it is supposed to represent a return to the traditional tasks of philosophy (p. 52).

This entails a belief in the “intentionality of consciousness,” i.e., that the reality of an object is inextricably linked to one’s consciousness of it, and thus a refusal of the subject-object dichotomy (p. 53). The idea if intentionality should not be confused with intention: intentionality stresses subject-object relationship (Sokolowski, 2000). From this arises the notion of “intersubjective validity,” which tests the researcher’s understanding of the essence of the phenomenon in a dialog with co-researchers. Thus, “intersubjective validity” involves returning to sources to have them verify results (Creswell, 1998; p. 207).

After bracketing, phenomenological data analysis proceeds through horizonalization, clusters of meanings, textural and structural descriptions, and concludes with the “essential, invariant structure (or essence)” of the phenomenon (pp. 54, 55). First, the researcher provides a full, naïve description of phenomenon from his or her perspective, and then engages in Imaginative Variation to consider a multiplicity of interpretations of this description. This is a form of bracketing. Once bracketing is complete, the researcher engages in phenomenological reduction. Phenomenological reduction involves horizonalization of data. The researcher identifies horizons of the phenomenon. Horizons are aspects that are essential to the description of the phenomenon. The researcher considers each horizon with equal weight, regardless of whether it is a word, phrase, sentence, paragraph, or an entire page. These are then grouped into non-repeating, non-overlapping categories called themes or “meaning

units." Based on these themes the researcher produces textural description of the phenomenon—what actually happened (p. 150).

Moustakas (1994) noted that horizons are "the textural meanings and invariant constituents of the phenomenon" (p. 97), and that "[h]orizons are unlimited. We can never exhaust completely our experience of things, no matter how many times we reconsider them, or view them. A new horizon arises each time that one recedes" (p. 95).

To illustrate the phenomenological process, Sokolowski (2000) generated a phenomenology of a cube. In so doing, he differentiated between sides, aspects, and profiles. We as observers are aware of the sides of a cube because they are indicated by aspects—i.e., from this perspective the side looks like a square, but from this perspective the side looks like a trapezoid. Beyond this, the sides can also have temporal aspects, called profiles. Sokolowski refers to a profile in the sense of a "sketch." If the observer closes his eyes momentarily, and then opens them again without moving, a new *profile* presents itself (pp. 17-19).

Sokolowski made an analogy to a sentence—like we see one side of a cube, or touch it, and apprehend the rest of it—so too, we recall what was said during a lecture and anticipate what will be said. Harkening back to Moustakas' definition of horizons as "unlimited" (p. 95), Sokolowski observed:

> It would be wrong, however, to say that the cube is just the sum of all its profiles. The identity of the cube belongs to a dimension different from that of the sides, aspects and profiles…As I move around the cube, or turn it in my hand, the continuous flow of profiles is unified by being "of" the single cube. [Sokolowski, 2000; p. 20]

In this way, the cube exemplifies the intentionality of consciousness. The ability of humans to interpret the overall identity of the cube transcends Cartesian epistemology.

After horizonalization, the researcher seeks a multiplicity of possible meanings and divergent perspectives of the textural aspects of the phenomenon. These emerge as the structures of the phenomenon, which are the co-researchers perceptions and intentions toward the phenomenon. In the end, integration of the textural and structural descriptions into an exhaustive, synthetic "composite" description yields the essential invariant structure of the phenomenon, or its essence (p. 150).

Creswell placed phenomenology on the "before" end of the theoretical spectrum, meaning that the majority of theoretical work is done prior to interviewing (pp. 85-87). Creswell defined a standard phenomenology as involving ten in-depth interviews lasting up to two hours, and notes that these can be supplemented by the "self-reflection of the researcher as a preparatory step to interviewing; depictions of experience drawn from outside the context (novels, poems, painters, etc.)" (p. 122).

Access issues associated with phenomenology are "limited to finding individuals who have experienced the phenomenon and gaining their written permission to be studied" (p. 117). Difficulties related to field duties concern bracketing, and trying to minimize the role of interviewer. Finally, phenomenology requires extensive transcription.

In terms of ethical considerations, Creswell (1998) made clear that qualitative researchers strive to protect the anonymity of sources. Being up front about research and not deceiving co-researchers is another of the guiding tenets of qualitative research. The importance of informed consent is paramount.

Reflexivity is a key component in the embedded rhetorical structure of a transcendental phenomenology (Creswell, 1998). This is both in terms of an initial,

autobiographical naïve description of the phenomenon, and in terms of the intersubjective validity that serves as a value check on the quality of research, in which understanding is tested "with other persons through a back and forth social interaction" (pp. 207, 208).

Creswell (1998) enumerated key components to establishing intersubjective validity, drawing from Moustakas: 1. Did the interviewer distort the subject's descriptions? 2. Was it an accurate transcription? 3. Were all possible interpretations of the transcripts considered? 4. Can the general structural description then be used to account for transcript excerpts? 5. Is the structural description situation specific, or does it extend to other contexts for the experience? (p. 208).

Transcendental Phenomenology

Creswell (1998) identified six strands of phenomenological research, and then focuses on the psychological, transcendental approach to phenomenology of Moustakas (1994). Moustakas elaborated on transcendental phenomenology, tracing it back to Husserl, and distinguishing it as having more emphasis on bracketing than other forms of phenomenology.

As we have seen with Sokolowski's (2000) example of the box, phenomenology refers to a way of knowing that is greater than the sum of the parts, i.e., we see a series of faces, and there are an endless number of vantages, but we intuit a box. Transcendental has a similar philosophical implication that becomes clearer through a reading of Heidegger, one of the founders of existential phenomenology. Heidegger (1975) explained the purpose of phenomenology. Sciences, like math and medicine, became divergent from philosophy, but he argues that philosophy is in itself scientific inquiry into the essence of reality. Thus, it is redundant to speak of a "scientific philosophy" (Heidegger, 1975; Paragraph 6, 7).

The German term Weltanschauung (Paragraph 10), or world-view, became associated in the 1830s with unconscious intelligence, as opposed to sense impression. Weltanschauung was favored as the mode of natural inquiry, the "independent, formative process of intuition," (Paragraph 12), i.e., serendipity. But the Weltanschauung, said Heidegger, is not theory. Rather, a world-view is linked to the being that we are (Paragraph 12).

Heidegger used the term being in the sense of driving-toward something. This idea that human beings are "comporting ourselves toward being" (Paragraph 20) lead him to the conclusion that knowledge of beings presupposes knowledge of being, and this is the essence that phenomenology seeks to draw out by means of an original natural science:

> We must understand actuality, reality, vitality, existentiality, constancy in order to be able to comport ourselves positively toward specifically actual, real, living, existing, constant beings. [Heidegger, 1975; Paragraph 20]

Philosophy was ontology for Heidegger. This distinction between beings and being was what he refered to as the "ontological difference," a transcendent observation, and thus philosophy is a "transcendental" science (Paragraph 41). The methodological structure of transcendental differentiation is the "a priori cognition" that being precedes beings (Paragraph 48). This, said Heidegger, is phenomenology, which is the method of ontology and thus philosophy itself. The phenomenological process is three fold: reduction, construction, and destruction (de-construction, the requisite flip side to the ontology, the breaking down of ingenuous theories through historicity) (Paragraphs 53, 54).

From Heidegger's rigorous definition, we see that transcendental refers to the idea that there is a being to be discerned outside of the subjectivities of beings, and phenomenology becomes the method to unravel this. While Heidegger is associated more

with existential phenomenology, and Moustakas (1994) aligned him with the tradition of hermeneutics, Moustakas evokes Heidegger's etymology of "phenomenon" to elucidate the meaning of phenomenology:

> Constructed from phaino, phenomenon means to bring to light, to place in brightness, to show itself in itself, the totality of what lies before us in the light of day (Heidegger, 1977, p. 74-75). Thus, the maxim of phenomenology, "To the things themselves." [Moustakas, 1994; p. 26]

In his first chapter, Moustakas identified five areas of human science research that he wishes to distinguish from transcendental phenomenology. These include ethnography, grounded theory, empirical phenomenological research, hermeneutics, and heuristics. These have the common elements of rejecting the normal quantitative model, and adopting more qualitative criteria for understanding the essence of things. Phenomenology is distinct because it relies on epoche.

Moustakas then defined transcendental phenomenology in terms of intentionality, intuition, a three-pronged methodology (epoche, reduction, Imaginative Variation), and intersubjectivity. He attributed most of the influence on his concept of transcendental phenomenology to Edmund Husserl, who was in turn influenced by Descartes. For example:

> The intertwining of subjective and objective knowledge in Husserl's thinking was also influenced by Descartes' (1912/1988) posture on objective reality, that "the object is said to possess objective reality insofar as it exists by representation in thought…for objective reality (i.e., the reality of representation) is in truth a subjective reality" (1912/1988, p. 249). In other words, perception of the reality of an object is dependent on a subject. [Moustakas, 1994; p. 27]

Though he was strongly influenced by Descartes, Husserl diverged from his philosophy. Husserl's phenomenology did not "employ deduction" to ascertain reality, but relied solely on intuition (p. 33). Husserl took the familiar Cartesian notion of empirical observation (as an antidote to purely subjective impressions) and sort of

inverted it. Husserl suggested that at the human level of interpersonal communication, no scientific model can substitute for cultivating an intuitive understanding of another person's lived experience. Thus, Moustakas (1994) distinguished between natural sciences, which investigate physical phenomena, and human sciences, which investigate mental phenomena. This is what Moustakas means when he outlines five areas of human science research, as distinct from the physical sciences. As Casey and Embree (1990) stated: "[I]t is unfortunate that 'science' has come to denominate merely 'natural' science, for certainly the human sciences, e.g., sociology and history, are sciences as well (and also 'applicable'), in which case the noun 'science' ought always to be qualified" (p. 151).

Interestingly, Moustakas (1994) enumerated forms of phenomena in his discussion of human science from a phenomenological perspective. He again divided phenomena into three groups: presentations, judgments, and emotions, or feelings. Presentations are "whatsoever that appears," whereas judgments are positive or negative reactions to these presentations, and feelings include love, hate, etc. (pp. 48, 49).

Moustakas (1994) noted that "[e]very mental act includes a presentation, a cognition, and a feeling" (p. 50). Husserl modified this, changing presentation to "act," and noting that it is possible for a phenomenon to be a "mental object" with "mental inexistence" (p. 50). Husserl changed presentation to "act" to stress the experiential nature of reality. The possibility of "mental inexistence," then, vis-à-vis an act explains how people make mistakes in ascertaining reality from a phenomenological perspective, for example, mistaking a mannequin for a real person. The point of phenomenology is to filter out these misinterpretations and experience "invariant meanings" (p. 51).

Perception is the primary source of knowledge in phenomenology, and this is intentional experience. Intentionality is meant not in the sense that we intend some goal, but rather that every perception is itself an act of consciousness. Perception refers to real objects, and is in this sense hyletic, or sensual (p. 56).

Creswell (1998) suggested that the textural description relates *what* was experienced, and that structural description relates *how* it was experienced. This delineation reflects Moustakas's (1994) discussion of noema and noesis (noeses, pl.) as they relate to texture and structure. In "intentional experience there is a material side and a noetic or ideal side" (p. 69). Noema and noesis are part of this ideal, noetic side of intentional experience: "…noema is that which is experienced, the what of experience, the object-correlate. Noesis is the way in which the what is experienced, the experiencing or act of experiencing, the subject-correlate" (p. 69).

Thus, the "noema, in perception, is its perceptual meaning or the perceived as such; in recollection, the remembered as such; in judging, the judged as such" (p. 69). The noesis is then the unconscious recognition that gives rise to the conscious perception, recollection, and judgment of phenomena. This is why noema is linked to textural description (conscious awareness), and noesis is linked to structural description (unconscious perceptions giving rise to the conscious awareness).

Moustakas' procedures for phenomenology, including formulation of the research question, ethical considerations, validation of data, methods of data collection and interviewing. His steps for analysis begin with horizonalization and horizons, which are grouped into lists of meaning units. These are then clustered into themes. The clustered

themes are used to develop the textural descriptions, and from these the structural descriptions are formed.

Finally, Moustakas discussed how to summarize the study by returning to the literature review to compare findings, discuss future implications for further research, and the potential outcomes of this study in terms of social meanings and personal meanings. He gave examples from studies spanning diverse topics, such as bypass surgery, to women's empowerment, to the experience of recovering from a closed head injury. Phenomenology has been tied to a number of studies, but has not yet been used to illuminate the experience of conducting military research, and its underlying philosophies and creative processes.

I and Thou

In his work *I and Thou* (1970), Martin Buber, a foremost Jewish philosopher of the twentieth century, stressed that people cannot understand each other as they do a thing—an I-it interaction—but that real understanding requires "openness, participation, and empathy." Indeed, he argued that in today's age the I-Thou relationship is eclipsed by the I-it relationship. Krippendorff (1996) cited Buber in his application of second-order cybernetic theory to mass communication. Krippendorff suggests:

> I know of no communication scholar who could communicate by the protocols of the classical theories they tend to perfect with their colleagues, for example, of communication as attitude change, as information transmission, as prediction and control, as management of meanings, or as institutionalized mass-production of messages. [Krippendorff, 1996; Paragraph 4]

Krippendorff situated Buber's concept of *I and Thou* in the context of non-trivial machines. A trivial it responds like a simple mathematical function of input and output, but a non-trivial it responds to external states, as well as dynamically to internal stimuli. Utilizing non-trivial machines as a model for human communication, Krippendorff

distinguished between two types of interactions defined by Buber—I-Thou and I-You. An I-You interaction is one of power-relationships, with iterative incorporation of the other person's point of view into an unending chain—as though braided together.

In I-Thou relations, there is mutual respect, unmediated empathy, and love. Krippendorff (1996) suggested that if a society degenerates into an I-You rapport—or worse, an I-It relationship of trivial machines—with its citizenry, then people may abandon thought in favor of "aggregates" (Paragraph 53). The axis shifts from democracy to mass democracy, and from governance to surveillance (Krippendorff, 1996).

The distinction between I-Thou and I-You interactions is relevant the question of surveillance technology in a democracy. The distinction is also methodologically important to phenomenology. Interpersonal communication is not merely internalizing a series of trivial facts and anecdotes that define others as if they were so much post-modern miscellany. This is the definition of an I-You interaction. Rather, it is important as a researcher to continually place oneself in the shoes of the co-researcher, to see things from his or her perspective. This is empathy, the definition of an I-Thou relationship.

I-Thou interactions are of relevance to journalism, and the role of a journalist is similar to that of a phenomenologist. Early models of mass communication, such as gate keeping, view journalists as passive conduits for the transmission of information (Roberts, 2005). Griswold (1999) identified a growing trend of specialization in American journalism. He suggested this might lead to greater diversity in news coverage, but that it could also lead to "increasing power over the uninformed" by elites (p. 193). Shoemaker and Reese (1996) documented the effects of media routines and organizational constraints on journalism, for example, in the case of the Gulf War. Buber

(1970) had important lessons for journalists in a media climate characterized by organizational constraints and specialization, forces that compel journalists to obtain trivial sound bites and snippets of information.

In his introduction to *I and Thou* (1970) Walter Kaufmann provided background for Buber's short book. He suggested Buber intended his book to be read deeply, and repeatedly. Although he was a religious philosopher, Buber is widely cited in communications literature, and wrote his book in a secular capacity. Kaufmann noted that Buber's notion of intimacy is linked to the Jewish notion of "return"—the idea that man can return to God simply through an act of will, an idea sharply contrasting Christian doctrine (p. 36). The intimation is that the individual—in the case of phenomenology, the co-researcher—possesses an almost religious significance, as though he or she is the site of divinity.

Choice of Methodology

Moustakas (1994) suggested two models of phenomenological analysis. These include the van Kaam method and the Stevick-Colaizzi-Keen method. The van Kaam method (van Kaam, 1959, 1966) includes seven steps:

The van Kaam Method (7 steps)

- The researcher begins with horizonalization of the data.
- The researcher then reduces these to fields, looking for invariant constituents. This is done with a two-step test:
  - First, the researcher asks if the horizon contains a moment of experience necessary and sufficient to understanding the phenomenon.
  - Second, the researcher asks if it is possible to abstract and label the horizon.
- The researcher clusters the invariant constituents into groups of like themes.
- These themes are checked for validity:
  - Are they explicitly expressed in the complete transcription?
  - If not, are they compatible with it? Otherwise, the themes are discarded.
- The researcher constructs individual textural descriptions, including verbatim examples.

- The researcher constructs individual structural description based on the individual textural descriptions and Imaginative Variation.
- The researcher combines these into individual textural-structural descriptions, incorporating the invariant constituents and themes. [Moustakas, 1994; pp. 120, 121]

From individual textural-structural descriptions, the researcher develops a composite description of the meanings and essences of the experience, the essential experience of the group as a whole (Moustakas, 1994). The van Kaam method differs from the method of Stevick, Colaizzi and Keen in three ways. First, the Stevick-Colaizzi-Keen method begins explicitly with phenomenological reduction and Imaginative Variation of the researcher's experience of the phenomenon. This self-reflection is not mentioned in the van Kaam method. Secondly, the Stevick-Colaizzi-Keen method is more iterative than the van Kaam method. There are fewer steps in the Stevick-Colaizzi-Keen method, but they are applied again and again to the data for each individual co-researcher. Finally, the van Kaam method places more emphasis on validation of data. The steps in the Stevick-Colaizzi-Keen method are as follows.

<u>Stevick-Colaizzi-Keen method (4 steps)</u>

- The researcher begins with full description of his or her experience of the phenomenon.
- From the verbatim transcript of that experience:
    - The researcher considers his or her description of the experience.
    - Records relevant statements.
    - Lists non-repetitive, non-overlapping statements. These are invariant horizons.
    - Relates and clusters these meaning units into themes.
    - Synthesizes invariant meaning units into a description of the textures of experience.
    - Reflects on the textural description, and through Imaginative Variation constructs a description of the structures of experience.
    - Constructs a textural-structural description of the meanings and essences of the experience.
- The researcher then follows this procedure for the transcript of each co-researcher.

- The final textural-structural descriptions are then integrated into a universal textural structural description that elucidates the essence of the experience. [Moustakas, 1994; pp. 121, 122]

The benefits of applying the Stevick-Colaizzi-Keen method include incorporation of the researcher's personal experience into the data, as well as exhaustive phenomenological reduction. The Stevick-Colaizzi-Keen method is more straightforward and procedural. However, because the researcher's personal experience of MAV technology is not as important in my study—because co-researchers are experts with more direct experience of the phenomenon—the van Kaam method was selected as a guiding methodology. As previously stated, for the purpose of my study researcher self-reflection is largely an exercise for bracketing. Self-reflection is crucial, but because the study focuses on a specific technology, the researcher's experience is not as vital to understanding essences as that of co-researchers. Furthermore, the van Kaam method is not as explicit in its protocol. It appears to leave more room for qualitative comparison and testing of initial horizons and invariant constituents.

The results of my study begin with the researcher's self-reflection on the phenomenon of MAVs to produce a naïve textural description of MAV technology. Imaginative Variation is then be a means to vary the meanings of this interpretation of MAV research. This free-fantasy variation of the implications of MAV technology explores science fiction, technological determinism, and ideal applications for MAVs. The primary purpose of enumerating these naïve textures and structures will be to enact epoche and get beyond preconceptions regarding the technology. Naïve textural and structural description of the researcher's experience will be in this case a form of

catharsis to identify and move beyond wild imaginings regarding the technology, and begin to see MAV technology for what it is through these architects' eyes.

Research Protocols

Institutional Review Board, Informed Consent and Security

Institutional Review Board (IRB) approval was obtained in January 2006, and the first official interview was conducted shortly thereafter. Participants received an informed consent disclosure sheet prior to the interview briefly explaining phenomenology, the minimal risk associated with the study, and that identities would be "kept confidential to the extent provided by law." This sheet is included as an appendix. All materials and documents relating to my study are kept under lock and key in the researcher's home. However, because MAV research at UF is high profile, the primary contact agreed that anonymity was not paramount. Any individual who wants to learn the names of researchers involved in the MAV project at UF need only log on to the Internet to obtain the names of professors and students. Also, as previously noted, BBC News ran a high-profile story on MAV research at UF. Still, all co-researchers are referred to with pseudonyms. The informed consent sheet specifically noted that if the research were to be published in a peer-reviewed communications journal, the names would be changed.

Evolution of Research Questions

Asking open-ended questions is vital to phenomenological inquiry. Relaxing critical thoughts into an open-ended set of highly generalized questions through bracketing took several months. It was an ongoing process that continued to evolve even the interviews concluded. The general protocol is listed as an appendix. Questions were not always given in exactly the same order, though interviews frequently began with the

broad question, “What is MAV research?” These questions also delved into how the researchers viewed aesthetics, inspiration, ethics and potential applications for MAVs. Preliminary questions involved asking about technical details of MAV functioning. It became apparent that the line of questioning should be more experientially oriented, intended to emphasize lived experience and obtain anecdotes. Thus, questions were added about how co-researchers’ family and friends perceived research. Interviews also probed for experiences at MAV competitions. Later, some questions about how creativity manifests in the course of research were added to the interview protocol.

It is important to note that because of the nature of qualitative research and phenomenology in particular, the research questions evolved over the course of the study. Thus, the preliminary interview questions (see Appendix C) still reflect initial researcher bias. They served as more of a branching off point for inquiry, and transformed over time. Ideally, the questions in phenomenology proceed from a general stance, and are not specific so as to be receptive to subjective impressions of the interviewee. The questions are tentative, representing the exploratory initial stages of the research.

Sampling

Interviews were conducted in spring 2006 at the University of Florida. This process was the culmination of two years of rapport building with members of the MAV lab, and networking through professors to contact graduate students. Creswell (1998) refers to nine major types of purposeful sampling, including maximal sampling, extreme case sampling, typical sampling, theory or concept sampling, homogeneous sampling, critical sampling, opportunistic sampling, snowball sampling, and confirming and disconfirming sampling. The sampling strategies employed in my study were maximal variation sampling, opportunistic sampling, and snowball sampling.

Maximal variation sampling seeks co-researchers who have different characteristics and traits. This was achieved by contacting both professors and graduate students, as well as by drawing from diverse walks of life and sub-fields in engineering. Opportunistic sampling selects samples that emerge during the research process. Networking through professors to graduate students was in a sense opportunistic. The professors and students were very busy, and thus if an engineer had the opportunity to talk to me then they were accepted as a co-researcher. However, the primary sampling technique used in my study was snowball sampling, in which a key person is identified to help find co-researchers.

Creswell (1998) recommended a maximum of ten co-researchers for a phenomenology. This number is small enough for the researcher to establish proper rapport in a reasonable amount of time. It is up to the researcher to determine when enough data has been collected to achieve self-consistency, called saturation. For my study, eight interviews were completed. The duration of interviews was one hour. A number of initial, rapport-building interviews were conducted with three of the participants as part of a previous series of journalistic articles. As these were conducted before IRB approval, no data from these interviews was used in this paper.

Co-Researcher Diversity

Participants ranged in age from their early 20's to mid 40's, most of the master's students were in their early 20's. One was in his early thirties. The two professors were in their early 40's. The MAV laboratory was predominantly American, but also included one Asian graduate student and one Canadian graduate student with ties to the Middle East. However, none of the researchers were females.

Stanley and Slattery (2003) examined race and gender in the field of engineering. Through qualitative interviews with various students to examine why female and minority students succeed or fail in an engineering curriculum, they determined that, in general, engineering students were reluctant to discuss issues of gender and race. While the MAV labs may not demonstrate great racial or gender diversity, they do demonstrate field-specific diversity. That is, it is an interdisciplinary program by its very nature, incorporating specialists in machine vision, aerospace, and electrical engineering, among others. Questions that arise based on co-researcher diversity include how age, level of education, length of involvement with the project, and ethnicity relate to co-researcher experience of MAV research.

Setting

The settings for the interviews were the classrooms and offices of the University of Florida Engineering Department. "Gator Engineering" encompasses several buildings on campus, including the New Engineering Building (NEB), Machine and Aerospace Engineering A (MAE-A), and Machine and Aerospace Engineering B (MAE-B). Micro Air Vehicle research is part of the Machine Intelligence Laboratory (MIL) at UF, which sponsors a number of other projects, such as the SubjuGator, a submarine with autonomous mobility that is nationally competitive.

Multiple laboratories within the engineering department are involved in MAV research, for example, the machine vision systems, and the flexible wing project. Graduate students and even some undergraduates are involved in the project. They attend weekly meetings at the MAV laboratory, which is located on the first floor of the NEB.

The laboratory is a single, institutional-looking room with white-painted cinderblock walls lined with heavy black slate benches. One large table sits in the center

of the room. Strewn about on these tables are pieces of carbon fiber, which are cut and shaped to form the MAV wings. There are a few computers. High up on shelves sit boxes of old, crash-landed MAVs. Posters displaying MAV designs and projects line the walls. One provides a colorful plot of wing-deformation. Another discusses the applications of MAVs to conservation biology.

The MAV lab was normally busy. Classrooms and offices provided a more suitable setting for interviews. Perhaps it would have been optimal to retreat to a neutral locale to conduct the interviews, and thus de-politicize the environment. However, due to the busy schedules, the engineering buildings had to suffice. These offices and classrooms reflected the functional nature of the MAV laboratory: white-painted cinderblock walls with minimal decoration, and frequently, high ceilings and windows. Professors' offices were carpeted and lined with neat rows of technical books on subjects ranging from machine vision to differential equations. The graduate student office contained a series of long desks with personal workstations. In the back of the room a box held haphazard retired MAVs.

Many such artifacts presented themselves. On brief visits to the MAV laboratory, MAVs of twelve-inch and six-inch wingspans were available for examination. Posters lining the walls of the engineering building described MAV research projects. The MIL web page also provided valuable information about project goals and participants, including flowcharts depicting the design process. Theses and dissertations were available online, and within these, diagrams of MAV subsystems. Intermediate documents in the design process—working diagrams, calculations on scratch paper, or

scrapped platforms on the computer—were not collected. My study drew mainly from transcriptions, personal observations, and online material.

Initial meetings involved either meeting with a professor in his office, or a student in his workspace. There was no compensation offered to co-researchers other than the opportunity to communicate with someone about their research.

The NEB is a brand-new engineering complex with a multi-story curved glass exterior wall. It is rather imposing. Upon entering, a curving staircase leads up the side of an atrium topped with a glass ceiling. The walls are white, and adorned with plane screen TVs that broadcast information about weather and events. Students surf the Internet at tables on the ground floor, taking advantage of the free wireless. One of the co-researchers was also the director in charge of the Center for MAV Research. His office was on the ground floor. The interview began with introductions as he finished an e-mail message. Large windows behind him framed green trees.

The meeting with Eric, a master's student working on the MAV project, took place upstairs in the MAV student study area at the NEB. The corridor curves toward the sterile looking room. Periodically, other students came in and out. One sat down and surfed the Internet at his workstation while Eric and I conversed. William, another 24-year-old master's student, agreed to meet at the MAE-A building across from the student union in a lounge area where several students talked shop in front of a muted television. To avoid the commotion, the interview was moved to an empty classroom, which contained only chairs and benches. The walls were bare, white painted cinderblocks. The blackboard was blank. The room had high ceilings and inaccessible windows, all under incandescent lighting. Overall, there was a minimalist air of functionality.

Data Analysis

The interviews were transcribed verbatim by the primary researcher, and printed. The interviews were read and re-read. Porterfield (2005) noted in her phenomenology of the experience of women living with HPV that "[r]eadings and re-reading are all a part of the hermeneutic circle of understanding or interpretation…Re-reading the interviews allows the researcher to ensure that the data obtained really answered the question that was asked and reflected the experience" (pp. 30, 31).

The researcher coded all interviews. Units of meaning varied from the individual word to entire sentences and paragraphs. These were highlighted using different colors. Initial codes and notes were made in the margins. Emphasis was placed on text that described the meaning of the experience for the co-researcher, to develop individual textural description of the "what" of experience. These codes were refined and reduced to fields of invariant, non-overlapping constituents—those deemed necessary and sufficient to the experience of conducing MAV research, and which could be abstracted and labeled.

These invariant, non-overlapping themes were then clustered into groups of related themes, and tested for validity on the basis of whether or not they were explicitly expressed in the overall text. One way to do this was to re-read the entire text. Another was by conducting random spot readings in the original interview, which will be discussed further in the section on validity. If the themes are not explicitly expressed or do not correspond to randomly selected sections of text, then they must at least be compatible with the overall themes of the original interview, a judgment-call on the part of the researcher. If the clusters of themes do not hold up to these three levels of scrutiny, they must be discarded.

Validated clusters of themes were used to formulate individual textural descriptions, again, the “what” of experience. These included verbatim examples. The researcher then varied possible meanings of the textural descriptions and arrive at individual structural descriptions, the “how” of MAV research. These were combined into individual textural-structural descriptions for each participant, including the invariant constituents and themes. The individual textural-structural descriptions were cross-examined against one another to elucidate commonality and discrepancies. Merging the individual textural-structural descriptions into one essential description of MAV research yielded a synthetic textural-structural description.

Three major areas of the experience of MAV research were addressed during each phase in the process, and these corresponded to the original research focus. First, the question of the meaning of the term “MAV research” was explored from the perspective of the engineers. This included illuminating underlying themes and contexts, universal structures (of space, time, materiality, causality, etc.), and any exceptional anecdotes. The question explored the lived experience of the co-researchers: what inspired them, experiences at competition, how friends and family understood their research.

Next, the MAVs were considered as “research object” in the sense of Bucciarelli, that is, as the product of active negotiation between engineers, contextualized in terms of a series of ephemeral artifacts (such as acronyms and working platforms) giving rise to a final product. The last question brought to light the creative processes at the level of the individual in producing the MAVs, and the corollary question of why the co-researchers chose this particular technological form as a course of study and self-expression.

Research Rigor and Axiology

Validation is a slippery process. Creswell (1998) commented on experiences that affect the initial orientation of co-researchers toward a study. He summarized criteria for evaluation of a phenomenological study:

- Did the interviewer influence the contents of the subjects' descriptions in such a way that the descriptions do not truly reflect the subjects' actual experience?
- Is the transcription accurate, and does it convey the meaning of the oral presentation in the interview?
- In the analysis of the transcriptions, were there conclusions other than those offered by the researcher that could have been derived? Has the researcher identified these alternatives?
- Is it possible to go from the general structural description to the transcription and to account for the specific contents and connections in the original examples of the experiences?
- Is the structural description situation specific, or does it hold in general for the experience in other situations?

The first criterion requires a more complex discussion and will be dealt with in the section on "Limitations" in Chapter 6, Conclusions. The second criterion involves the accuracy of transcription. To this end, the primary researcher performed all transcription to ensure integrity. Only I could recall the nuances of the interviews, having been present for the conversations. Synopses of the individual textural-structural experiences were e-mailed to corresponding co-researchers for member checks. This is also known as intersubjective validity, or confirmability.

Regarding criterion five above, another check on research rigor is transferability of findings. In this respect, researchers ask whether or not the findings have validity when transferred to another context, such as other forms of engineering research. This is a very narrowly focused phenomenology. Transferability will naturally be limited. Indeed, generalizability is not the goal of this phenomenology. Thus, the structural descriptions generated in this phenomenology were situation specific. However, the data might verify

Bucciarelli's concept of "research object," or theories of creativity. This could represent a form of transferability.

As far as the third and fourth criteria, his phenomenology placed primary emphasis on the text of the transcripts. Reading and re-reading were steps in a hermeneutic circle intended to arrive at truth. Imaginative Variation involved free fantasy variation of initial naïve description. Imaginative Variation also involved returning to sections of the transcripts to vary all possible structural interpretations that evoke the textural interpretations, as a check on validity. This was a similar procedure to spot-checking random sections of the interview text to verify themes and invariant constituents.

Random spot readings of the original interview were performed during the formation of themes and clusters from textural descriptions. They were also conducted during Imaginative Variation. Themes and structures should be reflected on every scale of the text, from the level of the sentence and paragraph to that of the entire transcript. The analogy is to a hologram. Unlike the negative of a photograph, if the template containing a hologram is broken a faint image can be reproduced from each piece. The groups of invariant constituents, clusters of themes, and structures in a phenomenology should exhibit the same correspondence to the interview text as the pieces of a hologram to the original image. Spot-checking ensures this is the case. The interview text could almost be said to exhibit a sort of fractal nature, if only metaphorically.

CHAPTER 4
NAÏVE DESCRIPTION AND IMAGINATIVE VARIATION

Naïve Description

In phenomenology, naïve description begins the process of bracketing. It is the researcher's initial interpretation of the phenomenon, incorporating reflexivity into the phenomenological process (Creswell, 1998; Moustakas, 1994). As the MAV may be viewed as a kind of robot, I will begin my naïve textural description with a brief history of robots in lore and in reality, and rigorously define technology.

Robotics History

Though the idea is very old, only in this century did the word robot come into being. Its etymology can be traced to the Czech robota, meaning drudgery, first used to describe artificial workers in the 1920 play Rossum's Universal Robots by Karel Capek. Created to help humans, the robots eventually take over the world (Jerz, 2002). A similar theme emerged in Isaac Asimov's I, Robot, a series of vignettes exploring robot consciousness. The book ends with the eerie sense that the giant, robot-constructed electronic brains somehow extrapolate and channel human destiny (Asimov, 1950).

I, Robot came out in 1950. Two years earlier, Harvard philosopher and MIT mathematician Norbert Weiner revamped an ancient concept in his seminal work *Cybernetics*. The term comes from the Greek kybernetes, or "steersman," coined by Plato to refer to effective government, and has since been used as a prefix for just about everything, from cybercafe to cybersex to cyborg. Weiner became interested in cybernetics after studying anti-aircraft fire control during WWII, particularly the

interactions of the operator and the steering mechanism. Weiner envisioned man as a component of technology in an automatic age (Weiner, 1972).

Robotics developed concurrently with cybernetics. In the sixties and seventies, hybrids began to emerge, such as computer science, artificial intelligence (A.I.), and neural networks (Heylighen and Josyln, 2001). Inventor Ray Kurzweil predicted that when A.I. heuristics meet advances in neural networks head-on, robot sophistication will increase exponentially, perhaps bringing Asimov's vision to fruition (Kurzweil, 1999).

At the present time, robots perform surgery, filtering out the natural shaking of a surgeon's hands, explore volcanoes, distant worlds, and Antarctica. There are modern commercial robots too, for example, iRobot's Roomba (an autonomous vacuum cleaner) (I-Robot Corporation, 2005). Teleoperation (operation at a distance) is an established sub-field of robotics. Teleoperation over the Internet is a brand new sub-field presenting interesting problems. Examples include a potential telerobotic system for remote handling of protein crystals on expensive Space Shuttle missions via the Internet, and the CoWorker, a roving, web-ready office robot with built-in tele-presence (Goldberg and Siegwart, 2002).

Inspired by designs from an early Japanese animation called Astroboy, the Honda Asimo robot debuted at the 2002 Robodex exhibition in Yokohama. Asimo once rang the morning bell at the stock market. It looks like a child in a space suit (Weiner, 2002) evoking one Japanese researcher's comment that anthropomorphic robots the size of children might make them less imposing (Menzel and D'Aluisio, 2000).

Technology

Mitcham (2005) equated the tendency to talk about technology as opposed to technologies as suggesting that technologies have some sort of essential feature. This is

technicity, which he traced from Aristotle's idea of techne (pl. technics), a great intellectual virtue, but subordinate to the flourishing of human nature. In fact, said Mitcham, Plato thought it was bad to remove techne from context. Galileo, Francis Bacon, and later Descartes attempted to extricate techne from human activities, study them in specific ways, and thus create technology. Mitcham suggested that in Mill's lifetime, technology was becoming seen as the science of means, and that thus *technicity* is the study of means divorced from ends.

Micro Air Vehicle Origins

Micro Air Vehicle research originated in a 1996 Defense Advanced Research Projects Agency (DARPA) initiative. Capitalizing on advances in micro-electromechanical systems (MEMS), which massively integrated small components, DARPA experts foresaw the emergence of a new kind of warfare for the twenty-first century, characterized by non-traditional urban environments navigated by small cells of specialized units. Micro Air Vehicles would reduce casualties and reconnaissance time, and provide foot soldiers with instant information. Because of the scale of MAVs, their aerodynamics is more akin to that of birds or butterflies than planes. They could also be used for tagging, targeting, communications, or tracking the shape of chemical clouds. They could even negotiate building interiors, or be mounted with weapons (McMichael and Francis, 1997).

Researchers at the Machine Intelligence Laboratory (MIL) at the University of Florida strive to make the MAVs autonomous. They filmed remotely piloted flights and created horizon-tracking programs based on these that allow the MAVs to distinguish between earth and sky, assuming the horizon to be a straight line (Center for Micro Air

Vehicle Research, 2005). Recently, the horizon-tracking software was abandoned in favor of an object-based vision system.

Though not an MAV, the Predator drone, which is "toy-like," debuted in Bosnia in 1995. On November 3, 2002, a Predator drone assassinated Qaed Salim Sinan Harithi, a senior Al Qaeda leader, and five associates as they drove through Yemen (Crandall, 2002). A recent article in the *Sunday Press Democrat* notes that Predators have been deployed recently by the CIA to target al-Qaeda members in Afghanistan, Iraq, and Yemen, with an unknown toll in collateral damage (Meyer, 2006).

Micro Air Vehicles also have application to search and rescue. The most dramatic recent example of robotic search and rescue occurred on September 11, 2001. Robin Murphy of the Center for Robot Assisted Search And Rescue (CRASAR) at USF descended with her team of graduate students on Ground Zero in the days after the attack, along with robots from private corporations, such as iRobot and Foster-Miller from Boston. Funding for these programs hails from the NSF, the Office of Naval Research, and DARPA's Tactical Mobile Robots program—in part the vision of DARPA's former director, Colonel Blitch, who partook in rescue efforts in Oklahoma City. Blitch still had the first generation TMR robots in his basement on the morning of 9/11, to be donated to the non-profit National Institute for Urban Search and Rescue. When the planes hit, he loaded up the robots into his car and called other robotics teams en route to New York (Lee, 2001).

To showcase the broad spectrum of MAV capabilities, since the inception of MAV research in the inception of MAV research in the late 1990s, MAV researchers have begun hosting competitions. The size of the competitions has increased from only a

handful of teams in 2000 to 14 in the 2005 competition in Seoul. The competitions have also become international events. Different competitions focus on different aspects of MAV design. For example, the 2005 Korean competition was geared toward rapid fabrication of the vehicle. The fall, 2005, European Micro Air Vehicle competition focused on constructing the best autopilot for a MAV.

The MAVs are comprised of a number of systems that work together to propel the machines and give them autonomy (Albertani, Stanford, Hubner, and Ifju, 2005; Plew, 2005; Abdulrahim, 2004). These include vision systems that use object-based software that allows the MAV to move autonomously. The vision system entails the use of a small camera mounted on the MAV. All hardware creates size and weight constraints on the vehicle. There are power systems, including a small battery. The propulsion systems include wings and propeller. In some versions of the MAV, the wings actually change shape, or morph. The wings are a lightweight carbon weave injected with a resin, which, when baked, hardens into a wing. Other sections of the wing are comprised of synthetic material as used in kites, which is flexible so as to provide more lift.

In all of these cases, the size and weight of systems, such as batteries, cameras, and materials for the construction of the wing and skeleton, create upper limits to just how compact the MAV can be. Furthermore, the aerodynamics at small scales (six-inch wingspan and smaller) create unique engineering obstacles. This is unlike the case of larger aircraft that can be modeled after birds, although the morphing MAV is modeled after a sea gull. The weight of materials and response-time required of on-board systems make the MAV a unique class of machine as the wingspan decreases.

Micro Air Vehicles are disposable military vehicles intended for eventual mass-production. They could be used for reconnaissance during war, or planting sensors to guide missiles to targets. Their wings are flexible enough to be rolled up and placed in a canister to be released from a missile to circle the impact and study it, or to be mounted on a police car.

On the other hand, MAVs hold potential for civilian uses, particularly in biological conservation. For example, MAVs will study migration habits of animals without disturbing them. Biologists frequently crash small airplanes while performing wildlife analysis. By replacing the biologist in the field, MAVs will save human lives. Micro Air Vehicles could be flown alongside windsurfers or rock-climbers to get pictures from extreme vantages.

Micro Air Vehicles in the News

Micro Air Vehicles have heralded significant coverage in the news over the past few years. A Lexis Nexis Academic search for "micro air vehicle" in news content from 2004 through 2006 yielded 47 articles, primarily from military, aerospace and technology oriented specialty publications, such as *Space Daily*, *PC Magazine*, and *Aerospace Daily and Defense Report*. Other regional newspapers such as the *Albuquerque Journal* and *Dayton Daily News* also covered MAVs, as well as the wire services Business Wire and UPI.

Many of the articles stressed military and surveillance applications of the MAVs, and the novelty of MAVs. Several of the articles focused on a 13-inch MAV under development by Honeywell, which according to the *Albuquerque Journal* is able to hover and survey a specific area (Webb, 2005). The article noted that the MAV is part of a $40 million contract with DARPA, and that it was expected to be combat-ready by the end of

the year. *Space Daily* covered the unveiling of a combat ready MAV recently ("High-tech micro air vehicle will battle with soldiers," 2005). Another article that ran noted that a DARPA Unmanned Air Vehicle (UAV) had was quickly being primed for the battlefield ("DARPA passes key milestone towards future combat ready system class I UAV," 2005). One UPI article focused on the morphing-wing MAV being produced at UF and its urban reconnaissance applications ("Mini-plane used for urban spying," 2005).

While a search of the *New York Times* from 2004-2006 revealed no articles related to "micro air vehicles," six recent articles related to MAVs were found in the BBC News archives for the same time period. These stressed applications for MAVs, including wildlife surveys, rescue operations, hazardous materials detection, and military reconnaissance. In April 2005, the BBC reported that 800 unmanned drones had been deployed over Iraq ("Allies plough billions into drones," 2005). However, another BBC article noted that UAVs could be used as low-cost, low-orbit satellites for developing nations ("'Eternal planes' to watch over us," 2006).

A BBC News article reported the morphing-wing MAV technology under development at UF ("Spy craft take gull flight lesson," 2005). The article noted that the researchers involved copied the "wing action of seagulls" to produce a morphing-wing MAV that could be ready for missions in two to three years. One of the co-researchers of my study was a source for this article. The article stressed potential surveillance and communications applications, and chemical sensing capabilities. It concluded with speculation that MAVs could eventually be used to plant small microphones, function in "swarms" that are disbursed from and communicate with a "mother ship" high above a city, and manufactured at the scale of insects within 20 years. They could be made

capable of changing color and form. Thus, MAVs are a rapidly developing technology with numerous military and civilian applications that have not yet been exhausted.

Imaginative Variation

After naïve textural description, the researcher varies possible meanings and structures associated with the textures in a free fantasy variation. Imaginative Variation at this point is primarily an initial exercise for the researcher to bracket preconceptions by varying the meanings of his own personal experience. In keeping with the van Kaam method, the structures outlined in this section will not be integrated into the final, synthetic structures. This Imaginative Variation is a poetic exercise for bracketing. It is also inspired in part by Don Idhe's (1996) Eden metaphor as a means to envision an alternative reality in which humans never use technology. In much the same way, I wonder what civilization would be like if MAVs were ubiquitous.

Novelist Thomas Pynchon (1995) brushed together the poetry of Rilke and mathematics. His characters themselves are ensnarled in mathematical architectures:

> …in the dynamic space of the living Rocket, the double integral has a different meaning. To integrate here is to operate on a rate of change so that time falls away: change is stilled... "Meters per second" will integrate to "meters." The moving vehicle is frozen, in space, to become architecture, and timeless. It was never launched. It will never fall. [Pynchon, 1995; pp. 301]

Technology can become poetry. Indeed, both Creswell (1998) and Moustakas (1994) suggested integrating fiction and poetry into phenomenology. Then, like in Pynchon's novel, I see superficial parallels between mathematics and the architectures. The curve of the wings of the smallest MAVs reflects the curve of integrals. The lines suggested a mini-UFO. There is the suggestion of something alien in the object of the MAV, and perhaps a little sinister.

The researchers permitted me to hold a seasoned, six-inch MAV. It seemed decrepit, and tattered, the plastic of the wings torn in many places. They assured me it had been through twenty crashes. I was struck by the seeming frailty of the tattered plastic and carbon-fiber wings. Contrast this with the deadly Predator Drone deployed by the U.S. military in Bosnia and the Middle East.

The contrasting fragility of the individual MAV strikes me compared with its destructive potential. This is especially relevant because the MAVs are meant to be produced cheaply, mass-produced, and deployed for military purposes. It could be used for planting sensors to guide missiles, or be mounted with a bomb to take out small targets. However, at the same time it contains the potential for conservation biology and a range of civilian applications, particularly for journalists. Thus the fact that it is lightweight is also contrasted with the great good it could bring to people by opening up new realms of public knowledge. In any event, what emerges is the understanding of technology as a double-edged sword, and this is one common view of technology addressed by philosophers (Mitcham, 2005).

There is implicit in the object of the Micro Air Vehicle the specter of the "War on Terror." The MAVs are part of the machinery of this new war. The MAV, then, embodies fears regarding the sacrifice of freedoms for safety. To me, the MAV represents a point of common interest to begin a discussion with scientists about their experiences and approach toward research. It represents an opportunity to open dialogue with engineers and better understand what values are implicit in their work.

Taken to its most dystopian end, the MAV technology could be a very destructive tool. Previously, I mentioned that my undergraduate thesis was a compilation of science

fiction stories that grappled with concepts in modern physics. I set the stage for one of these in a cyberpunk, psychedelic future inspired by William Gibson, Philip K. Dick, and J.G. Ballard. Other authors who have influenced me and that deal with the impact of technology on modern life—but blur the boundaries between science fiction and other genres—include Haruki Murakami, Thomas Pynchon and Jean Baudrillard.

Much of the writing of these authors deals with technology in a dystopian light. Mitcham (2005) noted that American engineering schools tend to divorce themselves from European philosophy and phenomenology. Perhaps in North America, science fiction is one of the few modes available to us to question the ethics of the progress of technology. For example, with the exception of Murakami, I had not read these authors before I composed my science fiction. It is as if their work had been incorporated so seamlessly into the fabric of popular culture that I had intuitively absorbed them into my own writing.

The term technology is derived from Aristotle's technics, which referred to the use of objects to manipulate the physical world and accomplish tasks. According to Mitcham (2005), Aristotle valued pure philosophy over technics. Important criticisms of the advance of modern technology (particularly regarding mass media) come from post-modernists such as Baudrillard (1994) and Virilio (2000). Baudrillard took the technological determinism of McLuhan to a bleak, postmodern extreme. Specifically, he suggests that the reproduction of digital images by modern media systems destroys meaning. He compared his philosophical writings to science fiction (1997). When he revisited some of the darker aspects of McLuhanism, Kroker (1995) spoke of humans as the "sex of the lifeless machine world," like the bee cross pollinating "the sex organ of

the machine world" (p. 8). This is an extrapolation of Heidegger's transhuman view of technology advancing for the sake of advancement. In a similar vein, Virilio (2000) faulted the ethics of unchecked advances in modern techno-science, likening them to the bravado of extreme sports.

Minority Report (2002) is a Steven Spielberg film based on a short story by the author Philip K. Dick. Tom Cruise is a police sergeant in charge of a futuristic division making use of so-called "precognitives" to apprehend criminals before they commit a crime. As an example of how science fiction could be used as a vehicle to broach ethical issues of technological development, O'Harrow (2005) cited *Minority Report* repeatedly in his survey of developmental surveillance technology. These surveillance technologies take the form of collaborations between government and private industry. The fact that a *Washington Post* reporter repeatedly references popular culture to illustrate his point is notable. Is *Minority Report*, like Orwell's *1984* or H.G. Wells' *The Shape of Things to Come*, a prophetic text? O'Harrow referenced the film in his discussion of complex data mining and facial recognition systems capable of catching terrorists before they commit a crime.

Minority Report (2002) is relevant to Imaginative Variation in that it also includes a scene with "spiders"—small, agile morphing robots that resemble arachnids. Police deploy the "spiders" to ferret out a suspect from a tenement. The residents are shown from a ceiling-eye view that sweeps from apartment to apartment. They are stopped stock-still in the midst of everyday activities—dishes, arguments, sex—to endure retinal scans by the scrambling "spiders." Will MAVs function as "spiders" for law enforcement and military?

Another image that has come to mind in the course of conducting this phenomenology is the 3-D Terminator ride at Universal Studios. In this ride, Arnold Schwarzenegger comes under fire from small, airborne drones as he makes his way to the A.I. nerve center of a future Earth hostile to human life, Skynet. As the ride is 3-D, one of the drones aggressively approaches the audience, exploding on impact. Since they are built cheaply and meant to crash land, some co-researchers mentioned that MAVs could be fitted with bombs and flown into targets.

More realistically, MAVs could place sensors on buildings to guide missiles, reminiscent of a scene in the Ridley Scott film, *Black Hawk Down* (2001). *Black Hawk Down* reconstructs the U.S. military's botched intervention in Somalia in October of 1993. In one scene, a soldier surrounded on all sides by raving Somalis throws an infrared sensor on top of the building in which he is hiding. The puzzled rebels pick it up, and too late realize that it is a beacon for a nearby helicopter, which swiftly and precisely dispatches them, clearing a path for rescue teams. In a preliminary interview, however, one co-researcher noted that he had no interest in war films.

To me, MAVs allude to such dark visions. On the flip side, MAV research holds the promise of eternal planes that watch over us. These planes provide ecological and cartographic data and inexpensive communications for developing countries. Micro Air Vehicles could be used for detection of chemical or biological hazards, as well as search and rescue. Co-researchers mentioned that MAVs could be used in case of natural disaster, such as Hurricane Katrina. Co-researchers mentioned that MAVs could be used by journalists to get images from unusual vantage points, such as during a surfing or rock climbing competition. Micro Air Vehicles could observe migratory patterns without

disturbing wildlife, such as manatees or sage grouse. They could save the lives of soldiers, as well as human researchers, who frequently die in plane crashes while conducting conservation research. Thus, in contrast to dark imaginings, MAVs inspire conservation, defense, and humanitarian applications.

CHAPTER 5
RESULTS

Micro Air Vehicle Researchers in Their Own Words

Now that we have explored the history MAV research and a variety of its potential implications—both positive and ominous—we are going to hear from the scientists themselves on the lived experience of Micro Air Vehicle research at the University of Florida. What follows are individual textural-structural descriptions for each of the eight participants. Through the process of horizonalization, the original interviews are reduced to fields of invariant constituents. These are then clustered into groups of like themes. The themes are checked for validity by comparing them to the original text. The textural component of the description consists of direct quotes and themes.

Multiple interpretations of these textural descriptions are considered, giving rise to structures, which are numbered in the structural component of the individual descriptions. Finally, a composite textural-structural description is formed using all of the individual textural-structural descriptions as a basis, revealing the synthetic description, or essence.

At each step in the analysis, every attempt is made to specifically address the research focus. This is to understand the experience of MAV researchers from the perspective of the engineers themselves through phenomenological inquiry, and generate an essential description. There were three corollary questions. First, why did the researchers choose this form of technology to study? Second, what does the MAV represent to the engineers as research object in the sense of Bucciarelli (2002)? Finally, what are the major creative processes at work in the MAV laboratories?

Dr. Davison: Textural Description

Dr. Davison, 42, specializes in machine vision for the MAV and is trained as a mathematician. He describes his research as centering on control of autonomous systems, mobile robots, and robot manipulators. When he came to UF's engineering department, he found a very strong aerospace department. While his previous research dealt with mobile robots he notes "equations of motion for some types of flight are similar to the equations of motion for mobile robots."

A typical research day for Dr. Davison involves meetings with graduate and undergraduate students to discuss progress on independent study, software development, and "hardware in the loop simulation." This simulation involves an artificial intelligence that takes the place of the pilot. This artificial intelligence tracks objects on a flight simulator. Dr. Davison's lab is currently mainly concerned with developing algorithms to improve the software. This particular approach to machine vision is not biologically inspired. It is not stereoscopic, but rather geometric or object-based.

The MAVs did not always run based on this kind of object-oriented software. After writing a proposal to the Air Force for a similar type of work, Dr. Davison took the place of one of the founding members of the MAV group. The individual he replaced worked on the original visions systems. Davison's object-oriented software replaced the horizon-tracking software. Dr. Davison formulated his response very carefully in describing this transition period. When further questioned about this, he said he just wanted to stress that his research was distinct from his predecessor's.

Davison was not initially interested in discussing the aesthetics of MAVs. He defined his inspiration in working with MAVs as relating mainly to pushing research boundaries. Davison was also initially disinterested in discussing the relevance of

biology to his vision systems. For example, stereo vision, way animals see the world, cannot be applied to MAVs because they're too small. He later elaborated:

> We're mostly inspired just by the mathematics part of the program, just by our knowledge, and we get excited about our parts of the MAV. I don't look at birds or get inspired by biology how other people do. It's more of the pure mathematics level for me.

When asked how he thought non-experts perceive MAVs, Dr. Davison was initially puzzled, then suggested that people might regard them as toys, or perhaps as a threat, but that still others appreciate their "coolness." He elaborated on "cool" to say that it meant "Intriguing. I think you know it's just a topic that excites people…cool is just kind of a word that captures general public interest in the area."

He noted military applications of MAVs, but also their search and rescue applications. For example, they could have been useful during Katrina. He referred to their small size that does not require FAA clearance, and their ability to "swarm" and provide video coverage of a large area.

Davison acknowledged that the government has the largest role in funding MAV research, and that they have been bought and sold primarily for military applications. However, he noted other more civilian applications, such as wildlife monitoring or forestry. Finally, however, he noted, "a lot of the stuff we do is just broad science. It can be applied, and it's not specific to the military."

In terms of impact on his personal life, Davison noted that his involvement with the MAV project has lead to personal success. The program itself is a success, and it has allowed him to meet distinguished colleagues, publish results, and attend conferences. He has traveled extensively in relation to his work, including Spain, the Bahamas, and

San Francisco. Peers seemed excited and enthusiastic about his research. Micro Air Vehicle research is "spreading like wildfire."

He felt the need "to be very mindful of the uses of the technology you're developing," and justified his own research as "more defense related." Micro Air Vehicle research is so new that there are no management, economic, or marketing precedents for "design choices." In terms of the control that the individual researcher has over the ethical considerations of his product, Davison noted:

> I think that [pause] 100% in their hands at some point. I mean, when we develop the Micro Air Vehicles, we don't know really what the Air Force is us—or what the military is using them for. I mean we have an idea, and you know, based on that belief, or that idea, then yeah, we feel comfortable developing a technology in a certain way.

Dr. Davison: Structural Description

Davison originally worked on equations for mobile robots, but easily transitioned into an aerospace department. As a mathematician, he was able to envision the mobile robot and the MAV—two totally different dynamic systems—in similar terms of equations of motion. Thus, his approach (1) transcended the physical differences between the two projects through the common language of mathematics.

The emphasis of his research continued to be on developing new algorithms to improve machine vision. However, because his emphasis was on vision for the MAV, Davison was not concerned about biological inspiration, as were other co-researchers. Neither had he attended any of the competitions. Still, he was still very enthusiastic about MAVs. He reported a (2) positive impact on his personal life, including feelings of success and commendations from colleagues, and exhibited energy and excitement.

Like other researchers, Davison pointed out that (3) MAVs are "more defense related" when asked about military funding. Davison emphasized saving soldiers' lives

through battlefield reconnaissance, search and rescue, and conservation applications. Though he was candid about military applications for MAVs, Davison formulated responses to such questions carefully, and at times seemed a little tense.

Davison referred to “coolness” when asked how he thought lay people perceived MAVs. He also said that MAVs could be perceived as a threat, or as toys. When asked about aesthetics, he said, “I wouldn’t say it’s not of interest, because it is appealing to look at a very cool-looking aircraft, and that does have an impact (on design).” The (4) aesthetic of “cool” emerged repeatedly throughout the interviews. The (5) toy-like quality of MAVs was something co-researchers frequently cited as a lay perspective that contrasted actual complexity from a design perspective. Davison linked it with “coolness in a technical geeky way,” but also with popular appeal of the technology.

In terms of inspiration, Davison referred to “trying to improve performance of the MAV” and “just trying to face those open barriers and discover what the open barriers are, and then just the challenge of trying to overcome them, I guess, is the motivation.” As a trained mathematician, Davison focuses on pushing “pure mathematics” barriers. Though the other MAV researchers are preoccupied with probing limits of physical laws, the (6) underlying drive to push boundaries remains the same for Davison.

In response to the question about military applications, he also replied “the government’s been the main funding source, although a lot of the stuff we do is just broad science, it can be applied, and it’s not specific to the military.” He also referred to his object-oriented approach to machine vision as being more compatible with reducing the size of the aircraft. Thus, his motivation for MAV research also involves pushing boundaries of (7) miniaturization to an extent. Overall, it revolves around producing (8)

generally applicable mathematics, and the challenge of (9) conducting pioneering engineering research.

Furthermore, Davison stressed that when he designs technology, he tries to conceive of it in such a way as to make it useful in multiple ways:

> I—I don't think, very few researchers develop a technology and think about it in just one way. I think, when people develop technologies, they're always thinking of different ways to leverage that technology. And I know, for myself, I'm always thinking about what are different ways that this could contribute to society, whether it's economics, or safety, or healthcare, [pace of speech accelerating] or economy or military. [pause]

Thus, (10) he conceived of technology in such a way as to "leverage" it on multiple levels. For example, he noted that sometimes it takes an event of the magnitude of Katrina to make people realize that they can use one technology for another purpose, such as the MAVs, which could have been used to locate people on rooftops. This perhaps explains his strong belief that (11) the researcher at one point has "100%" control over the ethical considerations inherent in a technology, a strong opinion not reiterated by other researchers. He clarified this to say that, in such a fledgling field, it is easier for the engineer to have power over the design process, because the management aspects are not yet set in stone.

Dr. Peterson: Textural Description

Dr. Peterson, 45, is the professor who oversees the MAV project. Thus, all of the other co-researchers work with him in some capacity, either as a student or collaborating on research. He received his Ph.D. in mechanical engineering, but switched to aerospace when he got involved in the MAV project at UF. The interview began with Dr. Peterson describing having recently gutted and refinished his vintage Airstream trailer. He had a picture of his family standing outside of it in the desert as his computer desktop.

Peterson gave a play-by-play description of winning the 2005 MAV competition in Korea. He described a "traditional surveillance competition," during which the team "took a video hit" and ended up winning only second. They scored third in the ornithoptor (flapping wing) competition. He conceded, "I don't think that any of us really understand how to do flapping correctly. Birds are way ahead of us there, and bats and insects." They placed first in the design report, and won first place over Arizona and the Korean universities.

Peterson pointed out how the 15 universities present at the Seoul competition represented a growing base for MAV research internationally. "It's definitely becoming more and more mainstream as far as university activity," he said. He also noted the UF team's victory in a recent European MAV competition. Participation was a spur of the moment decision. The UF team only had three weeks to prepare, while other teams had one year. They ended up sixth "with a very minimal effort."

Getting back to the bats and insects, Peterson talked about biological inspiration for MAVs. He noted some ways in which nature produces more adept small flying machines, as with some insects. However, he qualified this statement:

> [B]iological inspiration is important, but it's not the only inspiration out there. For instance, the biology is limited in what it can do. There's a design space that is not accessible to nature. For instance there are no rotary mechanisms in nature except for single celled organisms…It happens to be that rotary mechanisms are easy for us to produce…it is more efficient to keep with the rotary mechanism like a propeller.

Peterson's daily routine, like Davison's, centers on advising students. He oversees the MAV program, and as a result his advisees are more varied. He has some acquiring data on wing deficiency, or doing flow visualization, working in the wind tunnel. Others

are working on control systems, electronics, and hardware. Still others are working on specific missions, manufacturing algorithms, and autopilot development.

As for MAV applications, Peterson mentioned wildlife conservation and bomb damage investigation, though he could not go into detail on the latter. Applications were "limited only by imagination." He noted that the MAV team is working with law enforcement officials from Kentucky, where "a decent amount of marijuana is being grown." The team's goal is to produce an MAV disguised as a buzzard that can circle inconspicuously. Such an MAV could also be used for border control.

Peterson noted MAVs are primarily about surveillance. However, some research was done with sensor placement, e.g., chemical "sniffers" that The Air Force recently issued another request:

> So Micro Air Vehicle size combat vehicles that essentially have the ah [slight pause] firepower to for instance, um, attack maybe attack one person, or disable computers, or disable equipment. So you know essentially a Micro Air Vehicle with a tiny bomb on it could crash into a computer or blow it up, or crash into a jeep and take it out. You know, they could take out little targets as opposed to larger targets.

Peterson followed this up by saying, rather quietly, that he is "not pursuing it heavily." In terms of public awareness, he seemed to think that most people would have no idea what an MAV is, and once they found out they would think they were "cool," or envision a world where they are ubiquitous for surveillance. He suggested that they could have been used to increase the "speed and efficiency" of rescue operations during Katrina or similar missions. As such, he noted that they could be also be useful to the insurance industry. Finally, in a disaster situation, small MAVs would not damage helicopters or injure civilians if MAVs crashed into them.

Peterson became involved in MAV research because he thought MAVs were "cool." In this context, he noted that the idea of a flexible wing came to him while windsurfing, one of his passions. He thought the flexible wing idea was "fascinating." He has since become a leader in his field. Becoming "well known" in the field of MAV research was a "positive" experience. The research has allowed him to broaden into and contribute to new fields, which "obviously begins to help confidence level." Of course, it has made him busier.

I prompted for a "eureka moment," and he noted that the first few months actually getting something to fly represented the first major hurdle in MAV research. Nothing since had been so momentous, but indeed he hoped that receiving a DARPA grant to work on another class of aircraft, the 3-inch Nano Air Vehicles, would be a "test" to gauge their lab's respectability. Unfortunately, since the interview the UF team has learned that it was not selected.

Peterson also spoke of an effort to put all MAV "functionality" onto a single chip that included communications, actuators, and power. The way this works is to design the circuit on the computer, send it to a microlithography lab, receive 60 units and spend 4 to 5 months testing them. When asked how the microlithography works, Peterson smiled and replied, "I don't know how they do it."

To convey MAV research to the public, Peterson suggested first emphasizing the importance of the research in terms of national security, then presenting the challenges of research. This challenge meant "trying to fly smaller and smaller vehicles," pushing MAVs into a previously unattainable "flight regime." To Peterson, the ethics of

aerospace were not as important as in the field of biology. This was especially true since the applications are defense:

> In the area of engineering and aircraft design and understanding, I think there are very few ethical questions that we really worry about. I personally try to keep the vehicles that we work on in the realm of surveillance rather than combat, uh. I don't feel real comfortable working on a vehicle that's specifically made to kill somebody. You know, but, uh, if the vehicle is for surveillance then to me that's more of an area of saving lives, versus, uh, eliminating lives.

Dr. Peterson: Structural Description

Dr. Peterson began with a play-by-play of Korea, as well as mention of their placement in the European competition. He noted that the experience of MAV research was positive for him, that he has become a recognized figure in his field. His self-confidence has increased as a result. He also noted that MAV research has broadened his intellectual horizons and allowed him to investigate other disciplines. Thus, (1) pride is one aspect of Peterson's experience of MAV research. The field is growing, and Peterson feels that his team is a vanguard. Peterson therefore (2) exhibits a highly competitive nature.

Yet in terms of competing with nature, birds "are way ahead of us there, and bats and insects." Nature itself is viewed in technological terms. In fact, Peterson suggestsed that though it is frequently novel, "biology is limited in what it can do," and human ingenuity can devise morphologies that are more "efficient." That could be efficient in terms of maneuverability, or in terms of improving "speed and efficiency" of disaster response. Implicit in these statements is the (3) evaluation of efficiency as the primary objective of research, as well as the notion that technology subsumes nature—(4) nature is a subset of technology, not the other way around.

This is similar perhaps to Davison's "hardware in the loop" robotic test pilot in its emphasis on (5) removing the human from the equation if that is most efficient. For example, in his discussion of MAV applications, Peterson noted:

> But there's a big consortium developing UCAVs, which are essentially unmanned F-16's, except not quite that big, but probably equally lethal. So they're full blown fighter pilots without the fighter, and what that allows them is a much higher maneuverability, because, ah, right now they can produce an airplane that can produce more G's than a pilot can take. That's a limiting thing, the physiology of the pilot.

Micro Air Vehicle research involves a lot of routine. For a professor, this means mainly advising students. Micro Air Vehicle (6) research is decidedly interdisciplinary from Peterson's perspective as the coordinator of the suite of MAV labs. He mentioned his collaboration on machine vision for the MAV with Davison, a mathematician, and an aerospace professor. Machine vision is "a narrow topic, but nonetheless we're interacting."

Peterson offered up wildlife conservation applications for MAVs early on in the interview. He mentioned border patrol and law enforcement applications of a disguised MAV, but quickly follows up with wildlife conservation applications. Thus, there is a (7) tendency to play up civilian applications to balance or contrast military-oriented surveillance applications. Applications are only "limited by imagination," and this suggests that Peterson is also attempting to (8) design MAVs with multiple applications in mind.

As for the military applications, Peterson noted the Air Force's recent call for Micro UCAVs. He paused before mentioning MAVs with "firepower," and stumbled a little when mentioning that they could be used to attack individuals. Finally, he mentioned that he is not pursuing such an agenda heavily, and his voice dropped off.

There was (9) reluctance to discuss MAVs as offensive military technology. It was an uncomfortable topic. Peterson definitely favored viewing them as a "defensive technology" focused on "saving lives, versus, uh, eliminating lives," whether on the battlefield, or in the wake of natural disaster. Finally, it is important to remember that, as a result of viewing the MAVs as a defensive technology, from Dr. Peterson's perspective, (10) the ethics of aerospace research are not as important as bioethics.

Peterson felt that MAVs are a (11) relatively obscure technology, but if people knew more of them they'd think they were "cool." He himself became involved with them because he thought the project was "cool," and "fascinating." Thus, Peterson also referred to (12) an aesthetic of "cool."

His inspiration for studying MAVs came from his windsurfing experience. Indeed, he derived an idea for a flexible wing from his favorite hobby. Several subjects mentioned their interest in extreme sports, such as flying, ATVs, and racecars.

Peterson also spoke of an effort to put all MAV "functionality" onto a single chip. He noted that part of the challenge of designing MAVs is "trying to fly smaller and smaller vehicles," and pushing a previously unattainable "flight regime." The push to have (13) extreme experiences of the physical world through sports perhaps parallels the drive to investigate the extremes of the physical world through engineering, for example, in the sense of (14) miniaturization.

Eric: Textural Description

Like Dr. Peterson, Eric started off in mechanical engineering and switched to aerospace. He "kind of lucked into" MAV research. Eric is a 24 year-old graduate student, who realized that "research is really what governs graduate school," not classes. This is something that he did not realize when he was applying. After completing his

undergraduate degree here, he only applied to UF, assuming "it didn't matter." After searching "haphazardly" for an advisor, he signed on to work on a project related to MAVs. More recently, he made the full switch to working on the MAVs, and he's been with the project now for a year and a half.

Eric is not an airplane person, and perhaps sounds a bit guilty. Admittedly his interest in airplanes has increased since joining the MAV lab. What first got him interested in MAVs was the flexible wings—"adaptive wings." They were "fascinating from a structural point of view." He was intrigued by how they change shape based on ambient conditions. He describes the research as "almost a revolutionary kind of cutting-edge type of thing" and "very exciting."

Echoing the interest of other researchers, Eric noted the motivation centers around pushing "boundaries," and making something "cool." This drive is intensified, however, by the pride he takes in having an unconventional line of work:

> [I]f I had a real commonplace job for someone my age, I wouldn't be, necessarily, doing things along these lines. I'd be trying make money or trying to sell things to people, or bogged down with paperwork. So the ability to basically do everything that I want in the real of these small vehicles as far as research goes, really pushes you to try to think of new things to do, to try to come up with really cool, ah, just new ways to push the envelope.

He felt that in graduate research, there is real opportunity to do what you "love" as opposed to just working a job. He felt privileged to work on "just ground-breaking research, things that were inconceivable five, ten years ago," and senses the "rare" opportunity to "make that first step in any field" in a competitive time. This feeling of privilege is a "driving motivator."

Though proud of his work, Eric did not really care to participate in MAV competitions. He had not attended any. He considered this more of an "undergraduate type of thing," and "just not really worth my time."

Eric noted a change in his appreciation for airplanes since becoming involved with the MAV project. Micro Air Vehicle design has "really been streamlined kind of iteratively through a number of years." As a matter of fact, MAV designs at any university now reflect the designs of the UF MAV lab, he said proudly. But there are difficulties involved in the iterative process:

> And it's just months and months of failure and frustration and trying, and finally you walk across this one design, they usually call it the Edisonian approach, I believe, you know, Edisonian, like Thomas Edison. You know, you just kind of, you keep going, if you have some kind of glimmer of success, push along that direction.

Eric elaborated on his view of research as frustrating, painstaking, and plagued by dead-ends:

> And when you run up against a wall, since there's no textbook to look at and see what went wrong, because we're trying to be ahead of the textbook to a certain degree, it can be just a painful, painful, horrible thing, so you have the natural dichotomy, at least I certainly did, of loving it one day and hating it the next.

Though Eric greatly enjoys his work, he struggles with the iteration process. Friends and family also tease Eric a little for being a Ph.D. student, another source of frustration. He attributed this to the fact that other people might be slightly envious. Perhaps other people are starting out a job and it is "not quite how it's panned out to be." According to Eric, when such people see him doing what he enjoys every day, and in school as opposed to the business world, they tease him. Eric also noted getting "made fun of a lot because I'm also messing around with tiny planes all day." His happiness, however, is what is most important to his family.

It is difficult for him to communicate his research to lay people, but particularly such career-minded people, because there is an automatic assumption that what he is studying is too complex for them to understand. Thus he tries to keep communication "on the surface." In general, he felt that there are "no real conversations" that go on between he and his friends and family regarding his research. Many people in his field pursuing master's and doctoral degrees face similar problems getting their work across to others.

Eric pointed out that much of the government funding for MAVs comes from NASA. The government likes "to be the enablers," and he does not lose sight of the fact that they are really in charge. Like Peterson, Eric saw ethics as more pertinent to the field of biology. To Eric, ethics in MAV research means not stealing data:

> Ethics. Well, from our laboratory's point if view, if you don't do anything with animals, there's no biology involved that certainly gets rid of a lot of it. The ethical part from what we have here is just like making up results, and making results look better…Just make them look a little better. Just change the data points. That's the only issue I ever come across, and it's just something to be completely avoided at all costs.

Eric felt that "99%" of applications for MAVs were surveillance. Like Peterson, he suggested military applications, and followed up with wildlife surveillance. He noted that the wildlife surveillance could save human lives. Part of the reason MAVs are being developed is because frequently human pilots will crash airplanes while counting wildlife from the air. The MAVs would also be statistically better at counting animals because they lack the bias of "human error." Micro Air Vehicles can be set to sweep "dead set rows," i.e., to mechanically follow perfect rows, whereas humans have a tendency to fly toward an animal.

Finally, Eric spreads his time between six different labs, including fabrication, stress analysis, and the wind tunnel. It was the "pure interdisciplinary nature" of the MAV program that attracted him initially. He thought this interdisciplinary nature might be a bad thing career wise, because he was spreading himself too thin. Still, it felt good to be moving around and not just be sitting in front of a computer all day.

Eric: Structural Description

Eric approached MAVs from a mechanics perspective, initially drawn to them by his interest in the structural properties of the wings. Unlike many of the other MAV researchers, he was (1) not an airplane enthusiast, but has grown to appreciate them. He initially "lucked" into MAV research by default. He sounds a bit guilty or at least self-aware when he notes that he did not grow up an airplane enthusiast. Perhaps this is because he also felt it is (2) such a privilege to work on MAVs, which are "revolutionary," "cutting edge," and "exciting." Micro Air Vehicles are also "ground-breaking" and a "rare" opportunity to contribute to the "first step" in a field.

Eric's sense of (3) novelty and being the (4) vanguard of a field works in concert with the part of his persona that (5) refuses to see himself in a "common place job" for someone his age "bogged down with paperwork." He (6) takes great pride in the fact that he is working on exactly what he wants. This motivates him to do research, which in turn reinforces his sense of pride.

"Cool" came up again as a motivation, trying to "come up with something cool." The (7) aesthetic of cool is found in the context of pushing physical boundaries. The (8) desire to push physical limits goes hand in hand with the sense of pride Eric felt to be at the forefront of technology, which in turn validates his sense of pride in not holding an ordinary job. The privilege and pride also attest to his (9) strong competitive spirit, for

example, in his comment that it is “rare” to be able to take the first step in any field today because of laboratory competition.

However, although he had a competitive attitude, Eric had (10) no interest in MAV competitions. He also seemed sensitive about the fact that he was a Ph.D. student. He (11) defined himself in opposition to normal working people his own age just beginning a job in the business world, and who are a little disappointed. Perhaps as a result they are envious of him, because he spends his days “doing exactly what I want to be doing.” It is (12) difficult to communicate his work to non-experts, family, and friends because they assume automatically that it will be too complicated for them to understand. He senses many others in his field also experience this problem. Furthermore, people tease Eric about (13) playing with “tiny planes” all day.

Eric had a love-hate relationship with the (14) design process, which was “iterative” in that it was painstaking and time-consuming. However, it was necessary to streamline the MAVs over time. He described the beauty when things run like clockwork, and the “pure frustration” of hitting a dead end. These existed in a “natural dichotomy.” Eric is also both a scientist, and a musician. He loves his work one day, but hates it the next. These dichotomies are signs of a creative individual.

Perhaps it is no wonder that Eric frequents as many as six labs at a time. It is the (15) “pure interdisciplinary nature” of the MAV program that attracted him so strongly initially. Thus, he is a (16) person who enjoys communicating with many different kinds of people, and broadening his horizons in diverse forms of research.

Eric contrasted military applications with wildlife conservation, and noted that MAVs were “99%” intended for surveillance, that is, defensive applications. He seemed

(17) unconcerned about ethical questions, relegating those to the biological sciences. He also conceived of research ethics primarily as not stealing data. He saw government funding agencies as "enablers," and also, the entities to which the entire lab must ultimately answer.

Thus, in his mind the MAV (18) is a fundamentally defensive technology. Lastly, he emphasized that the MAV could save lives and make wildlife counts more statistically accurate. As well as stressing the defensive and conservation applications of the MAV technology, this repeats the theme of (19) removing the human from the equation of technology because the machine functions more accurately.

Mark: Textural Description

Mark, 26, an aerospace major, represents a different demographic. He has been flying since he was little. His grandfather was a pilot, and he recalls building his first RC aircraft with his dad. He stopped building aircraft for a while until college, when he began working with the MAVs. He found out about the MAV program and "fell in love with it," and now works in Dr. Peterson's lab.

He defined MAV research as dealing with a "different echelon of aerodynamics." His "interest and love" is tackling new problems, and being the first to come up with solutions. Though he did not consider himself an artist—software is not something people "appreciate, like, you know, the Mona Lisa"—he said that there is an "element" of art in aircraft design. To him, creativity is "creative new ways of solving problems," and the art in it is "finding unique ways to do things."

The problems he encounters are mainly design challenges, of which "streamlining design" is his sole interest. It is a balancing act of optimization. Later in the interview, he explained the design philosophy of MAV research:

> It's an iterative process, and that's just, that's not because we choose that method, it's just inherent to the design of the aircraft…one thing affects the other, and the other thing affects the other thing, so it ends up being they're related. They're couples and you have to iteratively arrive at a place where everything is balanced out. So that's where the optimization iteration comes into play.

Mark described the creative process as consisting of beginning with a design goal, brainstorming in a group, coming up with "wild ideas," and then narrowing these down to two or three to test. Design requires intuition, experience, and "crazy ideas." The crazy ideas are needed to make the designs novel for future marketability.

The group conducts flight-testing, but supplements the data with qualitative analysis. In fact, Mark was surprised by the amount of qualitative analysis involved in MAV design. He has found that leaders in the field consider it important to consider "subjective analysis" of aircraft design, that is, "aesthetics." As a result, the subjective opinions of more experienced pilots on the MAV team are taken very seriously.

Thus, to Mark, aesthetics are a very important consideration in MAV design. In fact, he referred to them as "just a new design goal to work around." He noted, "I think aesthetics are deceivingly important. No aircraft that I know of has been successful without someone who has very little knowledge of the actual performance of the aircraft approving it based on looks alone."

Another aspect of this design process is brainstorming. Mark has attended several MAV competitions. He described the pleasure of meeting people with common interests, playing pool, and discussing common challenges and sharing ideas. He described a typical day that varies quite a bit, from designing software, to discussing design challenges. He admitted that he spends a lot of time in the wind tunnel, even though he does not work there. "But you know, a lot of times, we spend a lot of time discussing, you know, what we're going to assess," he says. Much time in the labs will be spent

"catching up" as the topic gradually moves to MAVs. Dr. Peterson tries to cultivate a certain "laid-back" atmosphere.

However, Mark also expressed difficulty in communicating research to friends and family, humorously noting "they know I play with tiny airplanes." Even though, like Eric, friends and family tease Mark a little about his research, overall friends are supportive. His dad likes to wear his laboratory's competition T-shirt. Friends think Mark's research is "cool."

Mark also described having lots of experiences communicating with reporters at competitions, but adds that MAVs really are not a front-page story. He felt the lack of newsworthiness has made it difficult to communicate the significance of MAV research to a popular audience, for example, to the larger UF community. Mark also pointed out that communication is sometimes lacking within the suite of MAV labs, in that "the left hand doesn't know what the right hand's doing."

Mark identified his primary emphasis in the research as "streamlining" the design process. His motivation is to be able to go from scratch paper designs to an aircraft in a few hours. Essentially, he would like to be able to "rapidly iterate" designs, and he notes that it is the small scale of the MAVs that allows him to set this goal. Being able to "cheaply and quickly" iterate design is an "advantage."

Miniaturization, making things "smaller and smaller," is a goal. In this sense, Mark said that the lab is achieving some "science fiction things." He is an enthusiastic fan of science fiction. He recalled an incident where he went to a conference and an official played a scene from *Minority Report* (Spielberg, 2002) depicting small, spider-like robots

as an example of what the government wanted. He admitted that the military has the largest stake in MAV research, stumbling a little over his words.

In fact, Mark felt very grateful for the military funding, noting that "every day is Christmas for us," because they are always getting more supplies. A "graveyard box" of MAVs is tucked into the corner behind him. When asked about wildlife conservation applications, he noted that it is probably "less controversial," and "best of all doesn't threaten human life." Still, to Mark "research ethics" means not stealing other people's work. He takes an imaginative standpoint on the defensive applications of MAVs:

> I can foresee, not too far in the future, where the battlefield will just be more like a chess game of autonomous, or remotely controlled machines fighting each other on a battleground that has few or no people on it…hopefully, you know, these skirmishes and battles can be fought with minimal loss of human life.

Mark: Structural Description

Unlike Eric, Mark was (1) fascinated with flight since he was a boy, and had (2) previous experience as a pilot and with RC aircraft that allowed him to segue into MAV research. Mark also (3) spoke in terms of loving his work, and as a result (4) felt privileged to work in the MAV lab, where "every day is Christmas." He did not consider himself an artist, but (5) acknowledged an artistic component to his research. That artistic streak is associated with devising "unique designs" and "creative new ways of solving problems." Mark's (6) view of research and creativity centers largely on generating novel ideas.

Mark also clearly exhibited some (7) competitive spirit in his drive to be the first to come up with solutions. Other research goals that he kept in mind involve (8) miniaturization (making airplanes "smaller and smaller"), as well as "streamlining" the design process to speed up fabrication. There are the twin drives once again to (9) push

the extremes of physical reality, and (10) increase efficiency in terms of speed and productivity.

However, Mark also (11) referred to the “iterative” process, a balancing act of optimization. It is in a way “iterative” in Eric’s sense, that it is a painstaking process. But for Mark, “iterative” took on a different sort of meaning, one that implies the interrelatedness of the figure of the MAV—the interconnectivity of its systems—and therefore perhaps the overall (12) interdisciplinary nature of the project.

This community emphasis is reflected in the design process Mark describes. It involves a lot of brainstorming. Indeed, much of this is done in the wind tunnel, where Eric also reported spending a lot of time, even though he was not assigned there either. Meeting people of common interests at MAV competitions and talking shop over pool was stimulating, as was the “laid-back” atmosphere of the lab. Thus, there is a (13) communal and social element to the MAV research, one that is vital to Mark’s creative life. When this connection is strained—by difficulty communicating within the lab, or with friends and family, or to the larger university community—it is a source of some distress to Mark.

The fact that Mark (14) reported a large “qualitative” component to MAV design speaks further to this discursive aspect of the process. Not only is “brainstorming” in groups vital, but the subjective expertise of engineer-pilots on the MAV team is taken very seriously. Aesthetics become a new design goal. Thus, the MAV is an object of highly subjective negotiation among the researchers. In this case, at least, there is a confluence of aesthetics and functionality.

Mark was very candid about military sponsorship of and interest in MAVs, but tripped up a little when mentioning this, “So typically a lot of our design centers around (pause) centers around military application,” demonstrating (15) some discomfort in discussing military applications. Mark had a tendency to laugh a lot, perhaps nervously, during the interview. He seemed to genuinely be amused by the opportunity to reflect on his research.

Mark elaborated on wildlife conservation applications, which “best of all [don’t] threaten human life.” He placed (16) emphasis on MAVs as defensive technology. Yet (17) “research ethics” remained a primarily academic concept. Mark brought up *Minority Report* of his own accord. He (18) used science fiction as a means to envision future applications of the technology. He furnished very imaginative defense related potential applications of technology, including a future battleground where robots fight in the place of humans, “with minimal lost of human life.” Again, he stressed defensive technology.

Finally, Mark’s (19) concept of “cool” had to do with carbon fiber, which is lightweight yet strong, and quite expensive. This links the concept of coolness with both economy of motion—in that a lightweight object could also be strong—and with the notion of privilege, in that the materials are very expensive and therefore rare.

William: Textural Description

William, 24, has been flying Radio Controlled (RC) aircraft and full scale planes his whole life. He still competes internationally in model aircraft competitions. He flies, though not Boeings. Both of his parents are pilots, and he reports that they are intrigued by his research. They were his “inspiration” to become a pilot, and to design airplanes. He has been around airplanes all his life, and lived on a residential airport ever since his family moved to Florida. Having grown up as a pilot, the experience of flying airplanes

is “nothing out of the ordinary.” He is very accustomed to flying his own plane on vacations as opposed to taking a commercial airline or driving. William said he tries to maintain an appreciation this position of privilege, since most people do not have the opportunity to pilot an airplane themselves.

In fact, William originally had ambitions to become a pilot. He was a senior in high school when September 11, 2001, “kind of ruined” the industry. As an aerospace undergraduate at UF, William attended an American Institute of Aeronautics and Astronautics (AIAA) meeting. Two students at the MAV lab gave a presentation. Prior to this, William had never heard of the MAV program at UF. He’s been with the program for three years.

William said that he has had “no reason to look elsewhere” for work, because he is very satisfied with working on MAVs. He described them as “cutting edge. He noted that five years ago, people didn’t think MAVs were possible, essentially due to the effects of turbulence on small airplanes. His inspiration to work on MAVs stems from a desire to solve new problems, scale MAVs down, and do something that has “never been done before.” He enjoys being able to engage an academic problem with real-world implications.

As one of the MAV pilots, William described the experience of flying one:

> [I]t’s a pretty neat feeling to hold this 4 inch aircraft in your hand and think about how hard it is to see just from across the room, much less when it’s flying around up in the sky. It certainly gives you a unique sense of satisfaction, that, you know, I’m one of the few people in the world to fly that small of an aircraft.

Also, the option of changing constraints on the MAV provides a “never-ending challenge.” For example, he noted that competition constraints governed design as they scaled down. All dimensions of the MAV had to conform to five-inches, like a sphere

around the craft. This originated the unique circular wing design, making the MAV appear like “this weird exotic little flying saucer type thing.”

During his three years at the MAV lab, William participated in all three MAV competitions. He even joined in the US-European MAV competition last fall. Recall that this competition is oriented toward developing a MAV that flies autonomously (i.e., uses an autopilot). His lab had not done much with autonomy, he admitted, and thus they “weren’t very competitive, but we just went there to learn a lot and now this coming fall I think we’ll be very competitive.” He noted that the lab as a whole tends to “get competitive.” As competitive as William is, he noted that MAV competitions and international competitions are actually intended to “foster communication” between the various institutions working on MAV designs.

Yet, the barrier of MAV scale is “not quite as glamorous as the speed of sound,” and “most people on the street think, oh, a little toy airplane? Great. They don’t realize the challenges.” The MAV’s small size is misleading—they actually fly at a maximum speed of approximately 20-25 miles per hour. However, speed is not William’s primary concern. He is focused on reducing scale and fabrication time. His goal is to produce a robust plane that can crash again and again, that can withstand turbulence, and that is stable and easy for the pilot to maneuver. As a pilot, William noted that having flight experience is relevant to design, but overall flight experience is not that important to design.

The MAV Center at UF has several approaches to generating novel designs in the lab. In the past, the labs held informal internal competitions in which individual members built their own MAVs to demonstrate a promising concept. Another approach to design

is to apply constraints. William described how competition constraints governed design as they scaled down the MAVs. All dimensions of the plane had to conform to five inches, like a limiting sphere around the aircraft.

When asked about how creativity manifests in designing MAVs, William confessed "there is just a slight, ah slight artistic ah value of it." There is more than one way to approach MAV design because "there's no formula that says, you know, an F-16 should look the way it does," much less a MAV. Thus, it is largely a process of refinement through "qualitative assessment" and "form following function." It's not always necessary to make paper drawings if they have a sense of the "tool" on the computer. "So just about if you can dream it up, and if you can make a tool to lay it up on, then you can make it," he says.

Aesthetically, "carbon fiber looks cool." Getting back to how competitive the group can be, William aired a grudge with MIT. MIT draws a lot of funding for its "theoretical designs" that really aren't practical in terms of what can actually be done with MAV systems. This is "frustrating":

> [T]hey were able to get a lot of publicity over that design, the drawings of it, and they made a little model out of clay or something that was changed scale, but they have no motor for it, they have no camera like they claim would go in the nose, much less having the right prop or anything to fly it, yet it's all over the place and people see that, and that's one thing that has kind of hurt the MAV field. People see things like that and yet they don't fly. So people become kind of skeptical, and it also kind of raises expectations.

William stressed surveillance applications. Micro Air Vehicles should be represented in the press in terms of "strategic benefits" to soldiers in the battlefield. These were defense oriented. Micro Air Vehicles are intended for reconnaissance. William mentioned the six-inch "pocket" MAV, and enabling Kentucky law enforcement "to see what someone's doing in their backyard." Furthermore, he mentioned sensor

deployment of a MAV "swarm" for detection of radiological and hazardous materials, and the bomb damage assessment program.

William had no problem with the government funding. He jokingly said, "pays my paycheck (laughs)." The concept of research ethics was again linked to stealing others ideas, though he was initially confused as to whether that implied ethics of doing government research. He noted that, though it is a DARPA initiative, the MAV program at UF had not seen "one red cent" from the agency. Money mainly came from the military, Air Force special operations, and private companies. The MAV lab at UF was thus "kind of a second tier."

Finally, William noted that biology can be inspirational for design. He recalls a researcher who is using bumblebees as inspiration for a landing algorithm based on optical flow. A dragonfly is an example of nature surpassing what technology can produce:

> That's such a complex control system they have, and they're unbelievable flying machines, and so that's the goal to get to that and you know if that involves incorporating biological elements eventually it might but we're not quite to the point where I think our electromechanical systems have reached the end of their progress and we need to incorporate something like that.

<u>William: Structural Description</u>

William was (1) inspired to become a pilot by his family, and the fact that he's been around airplanes his whole life. Thus he is accustomed to flying in a way that the majority of other co-researchers are not. As a result, flight to him is "nothing out of the ordinary." It is second nature. Yet, he strives to maintain perspective, that not all people have the same opportunities to experience flight as he does.

Like his view of flying, William has a similar (2) sense of privilege regarding being able to work on MAVs. Although he also kind of (3) moved into the field by default, he

has “no reason to look elsewhere” for work. He is very satisfied. He described the unique experience of flying an aircraft as small as an MAV, that he is “one of the few people in the world to fly that small of an aircraft.” The work is “cutting-edge” and has “never been done before,” and thus he also stressed the novel aspect of conducting MAV research.

The (4) novelty of MAV research reflects William’s desire to engage new problems. In terms of motivation, this dovetails with producing smaller and smaller, faster and faster MAVs. William noted that pushing the boundaries of MAV size and fabrication time are key inspirations. He notes the (5) challenge of changing design constraints is also a motivating factor. It is a “never ending challenge.” Thus, underlying his motivation is a desire to (6) push extremes of physical boundaries.

Another way to express William’s research inspiration is in terms of practicality. William noted that he enjoys being able to work on an academic problem with real world implications. The notion of making a plane more compact, stabilizing the plane for the pilot, making a robust vehicle that can endure crash-landings, and streamlining fabrication are reflections of this (7) underlying valuation of pragmatic design. In fact, he is frustrated with MIT for producing designs that steal the limelight in MAV research, yet have little practical application.

Clearly, (8) competition is also a primary motivator, and William admitted that the MAV team is very competitive. They held internal MAV competitions within their own lab. William competed in MAV competition for three years, and feels confident his lab will be more competitive at the next European one. He noted the rapid advancement in

MAV research, and seemed proud that they have achieved what was thought impossible five years ago.

On the flipside, however, he emphasized that MAV competitions are intended to (9) “foster communication” between institutions working on MAVs. The purpose of internal competitions is to express personal designs to the rest of the lab. The initial stage in the design process is also brainstorming in groups. William showed slight (10) frustration in communicating the significance of MAV research. For example, he acknowledged that the average person on the street regards an MAV as a “toy,” not recognizing the design obstacles involved.

Although his flying experience has little influence on the way he approaches design, William noted that (11) qualitative analysis is key. No formula tells an engineer how a plane should look, he says. Form follows function, and sometimes, the team doesn’t even have to do a paper drawing. In terms of creativity, he feels if you can “dream it up you can make it.” William remained very open to inspiration for MAVs.

Aesthetically, “carbon fiber looks cool.” Throughout the interviews, (12) the aesthetic of “cool” is used again and again to describe the MAVs, and in particular, to the carbon fiber mesh, which is light but very strong. Perhaps “cool” evokes to the ruggedness of the system, which is also sleek and lightweight. Perhaps there is an artistic connotation to “cool,” as William noted a slight artistic influence on MAV design.

William noted that competition guidelines constrained design to a five-inch limiting sphere around the aircraft. This made it “look like this weird, exotic little flying saucer type thing.” William (13) abstracted the MAV and estranges himself from it as if it were an artifact from science fiction. Perhaps this can shed further light on what is

meant by “cool.” The odd shape of the MAV is a result of designing at new scales, and thus its morphology is a direct reflection of the previously uncharted dynamics at those levels. “Cool,” “exotic” and “flying saucer” are linked to the competitive drive to probe the boundaries of nature.

In terms of ethics, William (14) linked the concept of research ethics to stealing ideas, but was (15) aware of an ethical component to engineering machines for the military. He (16) stressed the defense applications of MAVs, though mainly in terms of battlefield reconnaissance, law enforcement, and sensor deployment. He did not mention applications to conservation biology. He was very adamant that MAVs are not weapons, and up front about military applications. His first response to questions about ethics of receiving government funding was to laugh and not that they pay his paycheck. Essentially, he was unconcerned about the issue of government funding.

For William, (17) nature itself is a subset of technology. Nature is a machine. Biology is inspirational for design. The dragonfly is one example. It has “such a complex control system.” For now, nature is more advanced on certain fronts, but William did not think that “our electromechanical systems have reached the end of their progress.” He could envision a day when human designs will rival nature. He noted nature never devised rapidly rotating parts—such as the blades of a helicopter—but humans can produce these cheaply and plentifully. This was one example where humans had an advantage over natural designs. What is implied is having an advantage in terms of the design challenges set forth earlier: MAV scale, fabrication, stability, and user control.

Steve: Textural Description

Steve is a thirty-five year old Korean national and model airplane enthusiast. He began working on model airplanes 25 years ago. He worked on remote controlled

airplanes in Korea from 1985 through 1995. He still flies his own RC aircraft every Saturday morning, and works on designs out of a home workshop. He won the Korean national RC-flying championship for a couple times "for the acrobatic stuff." When his aerospace professor in Korea asked him to develop an MAV he spent 1996 and 1997 integrating the components. But at that time the airplane had a 16-18 inch wingspan and ran on a gas motor due to a lack of efficient batteries. Steve is now the MAV fabrication lab director at UF. "I had a crazy time for the airplanes," he said. "I spent all night, all day, might skip school building airplanes. Radio controlled. I had lots of experience in this field."

Steve spends five days a week, eight hours a day on the job. Monday through Wednesday is spent fabricating the aircraft, and Thursday and Friday are spent testing them. He has attended many of the MAV competitions. Indeed, the 2000 MAV competition was hosted by UF. In that year, Steve found the MAV competition on the Internet, and asked Dr. Peterson if he could be the first foreign competitor. He and some "buddies" hopped on a plane and won second place in the competition. After that, Dr. Peterson asked Steve if he wanted to join the team.

Steve recounted a history of all the competitions, from Gainesville in 2000, to the European competition in Germany, to last year's Korean hosting. In late May 2006, Steve was part of the team that "dominated" in all three categories at the most recent MAV competition in Utah.

These days, although his lab has the capacity to make smaller planes, he has more interest in developing the 10-14 inch airplanes. These are currently more applicable, because they can carry an autopilot device. Steve also enjoys working on electronics,

such as video transmitters and autopilots. As an experienced pilot, he performs qualitative analysis of MAV flight. Thus, he can span multiple areas of the research:

> I work on every field and I like every part. This is a huge advantage in Micro Air Vehicle. We do everything small, tiny. You can integrate everything by yourself. And you can verify by yourself, so this is a very good project for, and especially for the school people.

Steve felt that attempting to define his design philosophy was difficult because there are so many contributing disciplines in MAV research. He preferred to talk about aerodynamics, which required wind tunnel testing, computer simulations, and actual flight tests. The airplane thus has a "different environment . . . like some small, tiny bugs, or insects." Aerodynamic research at those scales has a "different physical—physical philosophy."

In fact, aesthetics do play a role in design. Steve conceded that even in the flight regime of MAVs, "nice looking airplanes mostly fly better than ugly looking airplanes." However, instead of feeling that the MAVs turned out looking cool, Steve felt that the competition rules, which guide research overall, were too restrictive:

> [M]ost of our airplanes are turning out to look something like circular shape . . . But I'm not sure if that sort of circular shape is the best way to design. Definitely not. Definitely there is some different ways to design to optimize it to obtain different aerodynamic components. But these competition rules restricted so many things.

In terms of inspiration, Steve referred to the challenge of working on something that not too many people have worked on before, and the need for brainstorming and "lots of prototyping." When there is a problem, he stresses, there is no previous research to turn to, and the team has to rely on its own ingenuity. Steve also noted that the MAV research is inspired by biological designs, such as birds, dragonflies and butterflies, referring to these as a "design platform."

Steve was not shy about military funding. He mentioned that scaling down the aircraft is not the only project the suite of MAV laboratories have going. Steve is working on creating an Unmanned Air Vehicle (UAV) for Homeland Security that would be camouflaged as a bird. Military funding requires results, however. The designs need to be repeatedly tested. Thus, Steve noted that pressure from the military actually is a significant motivator to get things done, in that they require tested results and documentation. This was preferable to purely academic research. "You know, you make something, research or study for some progress, the research is a lot faster than just the study," said Steve. "It gave me huge motivation than just study."

Communication between family and friends has more to do with the competitive success of the MAVs. Steve says that airplane "stuff is not the common interest in my country." People in Korea think "it's a really strange thing (laughs)." However, on a trip to the MAV lab, his 3-year-old was "getting friendly with the airplane."

It was through the competitions that Steve became involved in the MAV project at UF. He is very open about his competitive nature. "Yeah, I really, I like, I like to be doing all type of competition." In his mind, winning at competitions is what cements a person as an expert in the inchoate field of MAV research, where it is "harder to judge who is the expert." The 2005 competition reunited him with colleagues last year:

> Oh, yeah, yeah, actually, you know, I had to visit all my friends. That's the funny part, but you know, that's the competition. You know, seems like some people blame me about, I'm a leader in MAV community in Florida, just for fun, but not seriously. But personally I have a good feeling, you know. I could give them more motivation to beat us.

In terms of creativity, Steve felt the push to "get more realistic results" and approach problems in novel ways. For example, to test tiny changes in pressure over the wings, Steve's lab improvised and put Jell-O at strategic points to measure how it

affected wing deformation. As a result of working on MAVs, he said his approach has shifted to data acquisition methods that provide more realistic data. He preferred a hands-on approach to testing airplane performance, as opposed to running computer simulations.

Steve mentioned applications for MAVs, such as military, law enforcement, and surveillance. He also noted another project he worked on, which was a MAV that could "crawl" underneath cars after landing on small wheels, for bomb detection. He developed the wildlife surveillance MAV for his master's thesis. He was inspired to do this after hearing about the number of fatalities due to plane crashes per year involved in wildlife conservation. However, he acknowledges that the military funds the project:

> I guess I have set up two uses for the more like human mankind, but most of our research we got money from the military for the war. So, many survive but I think I rather use the airplane for the more like for the human, mankind than for the war. [laughs] So we can say it's for the saving soldier's lives in outside, but they shouldn't kill somebody [laughs].

Steve: Structural Description

Steve is another example of an (1) airplane enthusiast who has made the transition into Micro Air Vehicle research. He found his way to UF via the Internet, which allowed him to enter the MAV competition in 2000. Competition is one of the primary motivating factors for Steve when it comes to research. He recoundted the past seven years of competition history and the UF team "dominated" the most recent meet, winning first place in all three categories. His family and friends are most proud of him for his success in competition, he feels. He is (2) openly a competitive person. When he returned to Korea in 2005, he joked with his friends about moving to Florida, but hoped that his (3) success could further communication and friendly competition.

On a similar note, Steve referred to the (4) challenge of doing novel research. He stressed that there is frequently no previous research to turn to when they are up against an impasse, for example, using Jell-O to test wing deformation. Thus, (5) ingenuity is a motivating factor.

So is practicality. Steve expressed a greater interest in MAVs with 10-14 inch wingspan because they could carry an autopilot. This made them more readily usable for the military. He repeatedly noted that (6) military sponsorship inspires a more pragmatic approach to research, one that is results-oriented and calls for documentation. Research with “some progress” in mind advances more quickly than “just study.” Through his involvement with MAVs, Steve has become more inclined to “get more realistic results.” He has spent a lot of time refining data acquisition to get this realistic data. Linked to this drive is a hands-on approach that he prefers to running simulations. Steve exhibited a (7) preference for tangible, practically oriented results. Thus, his creativity has shifted over the course of working with MAVs to be more pragmatically oriented and hands-on, rather than running simulations.

Steve also (8) acknowledged the importance of qualitative analysis, though he does not mention this term specifically. As an experienced RC pilot, he has “the skills to verify airplane performance.” Also important are (9) aesthetics, in that “nice looking airplanes mostly fly better than ugly looking airplanes.” In fact, Steve actually felt that the (10) competition rules were too restrictive. The rules resulted in the circular shape of the MAV, but that shape was not optimal in his opinion.

The (11) interdisciplinary nature of MAV research made it difficult initially for Steve to define his design philosophy. There are many contributing disciplines. He

preferred to discuss aerodynamics, but said he also enjoys working on electronics, too. He noted that he could work on every part of the MAV, and that this "is a huge advantage in Micro Air Vehicle. We do everything (?) small, tiny. You can integrate everything by yourself. And you can verify by yourself, so this is a very good project for, and especially for the school people."

Perhaps to an extent this speaks to the (12) community aspects of the research. The interdisciplinary nature of the MAV research is such that everyone knows a little about everyone else's research. Steve also showed (13) some alienation from his family and friends regarding his research. He felt that airplane "stuff is not the common interest" in Korea, and that people think "it's a really strange thing (laughs)." He felt his family is more proud of him for success in competitions.

Design philosophy also entailed a different "physical philosophy" because of the scale of the MAV. The MAV inhabits a "different environment . . . like some small, tiny bugs, or insects." MAVs are inspired by biological designs, such as birds, dragonflies and butterflies. These biological forms represent a "problem for humans" and a "nice design platform." Thus again, there was the tendency to be somehow in competition with nature, and to (14) view nature itself as a form of engineering. There is also (15) continued emphasis on scaling down the aircraft, though in Steve's case, he preferred to work on larger planes. For him, creating something that has immediate utility is of greater concern.

Steve was (16) not shy about military funding. In fact, Steve thought that the military funding helps to focus and expedite research. However, like his colleagues, he (17) stressed defense applications. First of all, he was the researcher who engendered the

wildlife reconnaissance MAV project. He stressed law enforcement and surveillance uses, as well as the unique crawling MAV for bomb protection. He could envision "two uses" for MAVs, military and civilian. Even the applications for war are so that "many survive," and for "saving soldiers' lives." He preferred to see the MAVs used for humane purposes, but could not suppress a nervous laugh.

Joseph: Textural Description

Joseph became interested in the MAVs while boning up on his golf game in high school. He became fascinated with the Magnus effect, whereby a spinning object is able to produce lift without wings. He created a plane for a high school science fair project based on this idea, and later presented it to professors at the MAV lab. They asked him to join. He is now going into his eighth year in research at UF. He is pursuing his Ph.D., and wrote his master's thesis on morphing MAVs.

Joseph also has attended four competitions with the MAV team. Each time he went, he assumed the role of pilot. He assumed this role because when he first joined the lab he already had RC flying experience. The professor who had been flying for the team was getting ready to retire. Joseph asked if he could fly one day, and did very well. After that he was the honorary pilot, a case of being in the right place at the right time.

The pilot's job is to fly the MAV to a target in various competitions using a set of VR goggles. He related the competitive spirit to golfing, or track, or mountain biking, except it was a little weird at first because "you're talking about flying…part of the competition is just sitting at the table and putting two wires together." The pressure was intense because all of the other teammates' efforts culminated in his successfully obtaining the target.

Joseph spoke very rapidly throughout the interview. His train of thought ranged freely across disciplines. He is also a trickster of sorts who enjoys ambushing colleagues with a rubber chicken for a photo opportunity. He spoke of being "obsessed with" the flexible wing MAV, as it "embodies" what he would like to contribute to his field. He sees it as a "microcosm" of what he intends for his career. Joseph referred to his work on the MAVs as "fun." He hesitated to call himself "creative," though he refers to a creative process involved in MAV research. He was "obsessed with" the popular 80s toys, Transformers, and noted that he and lab mates have considered equipping MAVs with Transformer sound effects:

> I really like Optimus Prime. I like Megatron not so much, but the point is you see all these robots that change shape. Well I just bought a Transformer a couple of months ago, a little toy, here. And the interesting thing is they've solved a lot of their joint mechanism problems that I'm dealing with right now.

Another "hopeless passion" was photography. Joseph recalled spending days at the beach taking pictures of seagulls. Nature was "one of the most perfect sources" of inspiration. Joseph thought of photography as an attempt to "spy" into the world of birds, looking at dive maneuvers, joint angles, and "individual centers" of gravity. He even aspired to analyze deployment of individual feathers, though he admitted "[t]hat stuff is still way beyond our level."

The Canadian-born son of a Syrian immigrant and a devoted Muslim, Joseph openly refers to a "Creator," and claimed that his work tended to reinforce his faith. The experience is "humbling." He is one man working on one aspect of MAV flight, yet he appreciates the confluence of the systems in birds. "The mechanisms the birds have in place," he said, "the multidisciplinary nature of these, how everything, just the feathers,

have a function, so many different aspects, from structural to aerodynamic, to control, and they all work together."

Though he loves Transformers, inspiration for Joseph came not so much from science fiction, but from video games and movies. He made the connection to "popular culture" and "futuristic stuff." One of his side projects is analyzing "drifting" in cars. He has a web site devoted to it. He traced his interest in drift to watching chase scenes in movies. Now he watches movies for airplane scenes, or car scenes.

Joseph is also a trained pilot, and enjoys skiing and mountain biking. He rides a folding kick scooter around campus, rather self-consciously. He said he's only really "enjoying" himself when he's "not touching the ground." He took the "cop out" answer that he is inspired by everything, but this is significant because he says that he can draw inspiration from unrelated problems.

Part of his approach is attempting to see parallels among disciplines. This involves abstraction of the project to an extent that he is "looking at the pure science of it," rendering applications almost irrelevant. He further explained in terms of his use of analogy to explain concepts such as drifting to fellow aeronautical engineers who are not be familiar with the concept:

> But the thing that you find is that if you abstract the systems, you can make these connections in fact very rapidly. If you consider an airplane on its side, two wings right in front of the other, that's just a car. So the same aerodynamic forces that affect it are the same forces that affect it are the same traction forces that affect the car. And so in that sense, everything that I've studied in terms of my airplanes is applied to my drifting car, and back and forth between the two.

Joseph used the analogy of birds to convey his research to others in his field. Seeing parallels between the flight of birds and drifting of cars underscored the level of abstraction in Joseph's thought, which takes ultimate form in the concept of the control

system. Joseph's specialization is "controls dynamics." The control system is basically the program that makes the MAV fly autonomously. It is the dynamics of flight abstracted into mathematical algorithms. This is the mathematics he mentions above that collapses the systems of a car and a plane into one common language that allowed Joseph to easily segue between them in discussions. To him the control system is "a beautiful representation of the world" because of this explanatory power. It is also what distinguishes the MAV from RC aircraft:

> So the beautiful thing about a control system is you're actually making the system work. And that's how I feel it fits in, because you can do it everything on the Micro Air Vehicle. You can do the actuators you can do the structures you can do the structures, the aerodynamics, the propulsion, but if you haven't done the control system, it's just a toy.

Part of the advantage of working on MAVs is not relying on analogy as much as in other fields, such as biology. The MAV is a tangible artifact, not an invisible microbe. Joseph greatly valued the scale of MAVs. Speaking very fast, Joseph noted that the MAV researchers are in "such a beautiful position." Micro Air Vehicles are "so ripe" for experimentation. Any larger, and they would require a pilot, and they would not be able to test as many prototypes. Any smaller, and there would be no parts. This is a "sweet spot" in terms of research. If the MAV crashes, at worst it would hit a school bus window "and the kids will laugh." There is little risk to people, and "huge" opportunity for novel science.

As someone who appreciates the confluence of systems inherent in nature, for example, a gull, Joseph demonstrated interest in all aspects of the MAV. Though he is a "controls person," he likes to build, too, though everything "leans toward" dynamics. He doesn't want to "sit at a computer all day."

Joseph claimed to be “in love with the shape and the form of aircraft,” which are “beautiful.” He linked aesthetics of MAVs to those of airplanes in general which are an “art form.” However, due to small aircraft size, there are geometric constraints that make aesthetics “secondary considerations.” Thus, his aesthetic touches take the form of details, such as wingtips. Still, some decisions are arbitrary at their “level of analysis,” such as the crisscrossing of carbon fibers to form the MAV skin.

There was an element of qualitative analysis in Joseph’s work. He described a reciprocal relationship, whereby flying affects his design work and vice-versa. When flying the MAV manually “you become the control system.” Pilots therefore have a realistic idea of what a MAV can do. The purpose of flight-testing is to “excite the aerodynamics” by performing precise maneuvers, and therefore RC skill is integral. Being a pilot also gives him an edge when he reflects on data, in that he can better understand how the numbers represent airplane dynamics and response.

The labs working on MAVs may be interdisciplinary, but communication could be better. Joseph felt the level of involvement only allows researchers to see what is immediately before their eyes. Researchers belong to certain reified “structures” within the field of engineering that make it difficult to “see” connections between the research. Researchers are so focused on developing their own part of the project, they expect the other parts to “magically appear,” while hoping their particular research focus will be the “key that helps solve the major problem.” He referred to this as “segmentation,” although during the competition such differentiation was a necessity.

Communication with lay people and friends and family reflected a different problem. Joseph felt that most people’s perceptions of his research are “rudimentary”

and "visual." Family and friends understand morphing, and the concept of increased performance through aerodynamic designs but the "details are lost," despite the fact that his parents both hold advanced degrees, albeit in unrelated areas. Communication to lay people definitely relies on the "visual." Reporters recently caught wind of the morphing MAV story and inundated his lab. Joseph expressed the sentiment that reporters specifically want brief synopses that consist of "visual images."

Finally, when asked about uses for MAVs, Joseph stressed defense applications, such as saving soldiers lives through battlefield reconnaissance. Other applications included wildlife conservation, law enforcement, and even insurance. His speech accelerated at this point in the interview, and he stumbled over his words occasionally. As the son of a Syrian immigrant, and himself a devout Muslim, he expressed concerns that the MAVs could be used in the Middle East in an offensive capacity, but stressed that his primary interest was pure research.

Joseph: Structural Description

Joseph (1) got into MAV research after being an airplane aficionado for years. He flew both RC aircraft and held a pilot's license. A (2) sense of privilege characterized his attitude toward MAV research. Not only is he self-described as "obsessed" with MAVs, and being "in love" with the shape and form of aircraft, Joseph also referred to the (3) "sweet spot" of MAV research, and their being "so ripe for experiment." There is little risk, yet big opportunity to do science. For Joseph, the idea of (4) privilege is also linked to doing novel research. However, in his case it has less to do with occupation and more to do with the actual scale and physical constraints on the aircraft.

Joseph had a tendency to speak very rapidly and connect from idea to idea. He was obviously (5) excited about the research. As mentioned, he referred to being "in love"

with aircraft and “obsessed” with morphing MAVs. Photography, one source of inspiration for his research, was a “hopeless passion,” though he hesitated to call himself an artist. Joseph even called his work “fun.” For him, (6) obsession, inspiration, and passion characterized the research.

He even mentioned that the (7) MAV research reinforced his faith. Nature was a “perfect” source of inspiration, and he saw the systems working together in birds. Associated with his work were a (8) sense of humility and religiosity. He even mentioned God. Joseph also projected a sense of humility. Yet this was less occupational humility, and more a sense of awe in the face of nature. However, the flipside of this is a tendency to (9) regard nature as if it were a particularly advanced (10) form of engineering. Birds are made up of subsystems. His (11) ratiocination deconstructed them into dive maneuvers, joint angles, and individual centers of gravity. Deployment of individual feathers is “still way beyond our level.” Later, when commenting on the value of having real flight experience in understanding MAV performance, he said that it is like “you become the control system.”

There was a (12) playful irreverence in Joseph’s manner. This was a man who likes to ambush people with a rubber chicken and a camera. One of his central inspirations was Transformers, and particularly Optimus Prime. He described himself as being inspired by video games and popular culture. Questions about drifting arose from movie going, and now he says he watches movies for the car and airplane scenes. He studies race cars. He is into mountain biking, skiing, and flying, and says he’s only happy when not touching the ground. His work is “fun.” Also, however, there is again (13) the link to pushing physical boundaries, through sports as through research. This

drive to test physical boundaries is (14) connected to the drive to compete. Joseph noted that nature is “still way beyond our level,” and he has felt the pressure four times as a pilot in MAV competitions.

Abstraction is another aspect of Joseph’s research. He praised control systems for their general applicability. Birds themselves are abstracted into an interweaving of engineering systems. He noted that he has (15) mathematically abstracted his work to the extent that pure applications are almost irrelevant. Joseph equated a car and an airplane in a pure mathematical space to communicate research to a colleague. This also (16) underscores the interdisciplinary nature of MAV research. He gave the “cop out” answer that he is inspired by everything, because you never know when something will be useful to solve a “completely different problem,” such as with the golf ball and Magnus effect. He mentioned that he is a controls person, but likes to build, too. Thus, there is a tendency to work on different problems within the lab, and also to look outside of his field of research for inspiration. However, he qualified this by saying that there are many subfields within his area of research, but all have specific applications to MAVs.

In terms of communication, Joseph noted that he is (17) big on metaphor, and that analogy can be used to relate ideas about abstract concepts to people in different fields, for example, the analogy from car to airplane. Birds are used quite frequently as analogies. However, part of the advantage of the MAV research is that they do not have to rely as much on analogy to impart the meaning of research to other engineers. Analogy (18) can be useful to convey research to friends, family, and lay people. Joseph felt strongly that (19) reporters require visual images. Friends and family understand on

a level that is “visual” and “rudimentary.” “[D]etails are lost” on his parents, though they hold advanced degrees, just not in engineering.

As a result, (20) most meaningful communication about MAVs takes place within the labs. There is difficulty here, as well, however, in that the level of involvement only allows researchers to see what is immediately before their eyes. Everyone is so focused on making their aspect of the project the key element that they just assume other parts will “magically appear.” Joseph alluded to “structures” in the world of engineering that make it difficult to “see” what others are working on. There are limits on the interdisciplinary nature of the labs, mainly due to (21) over-emphasis on specialization.

As a pilot, Joseph mentioned the (22) importance of qualitative analysis. He described the reciprocal relationship between flying skills and MAVs. Being a pilot gives the engineer realistic insight into the performance of the MAV, and ability to reflect on data. For all his irreverence, there is a very practical side to Joseph. Without a control system, a MAV is “just a toy.” He is in “love” with airplane aesthetics, which are “beautiful” and an “art form.” In the case of MAVs, however, aesthetics are “secondary considerations” due to “geometric constraints.” Aesthetics (23) are a source of inspiration for research, but practical considerations are paramount.

Joseph placed emphasis on defense related applications, such as battlefield reconnaissance, wildlife conservation, law enforcement, and insurance. His speech accelerated when I asked this question, suggesting great excitement. His tone was mirthful, but he tripped over words. He openly acknowledged the difficult ethical position of, for example, being of Middle Eastern descent, and a practicing Muslim, yet that the MAVs could be used in the Middle East. To this end, he (24) re-emphasized the

defense applications, and pure research aspects of his work. This subject was received with some nervousness. Joseph's speech accelerated and he stuttered slightly as ideas were carefully articulated. But they were also received with a hint of mirth, perhaps in the spirit of his irreverence. He concluded the conversation with the sense that this was an (25) open-ended ethical consideration with no easily articulated solution.

Lewis: Textural Description

Lewis, 22, an aerospace major, was the only undergraduate interviewed. He has been with the MAV project for three years, and only transferred to the morphing wing lab a year and a half ago. As such, he is still the "new guy" in that lab.

A Gainesville native, Lewis was not an airplane enthusiast as a child, but rather got into RC flying in college. He met other members of the MAV lab who shared common interests through classes, and started working with them.

Currently, Lewis is working on a special MAV that sweeps its wings from front to back. He looks to birds for inspiration, using online pictures and photographs that he and Joseph took at the beach of gulls. He has been studying the dive of a falcon, to see if flight dynamics are beneficial to a mission in an urban environment. He likened the range of motion of the wings to that of a rising phoenix and a diving falcon. He was the first to research this design, and would like to see if it is beneficial to "some sort of flight regime." The goal in emulating a bird is maneuverability and agility in an urban environment.

Other inspiration lies in the "freedom" and "passion of flight." Lewis is learning to fly. He flies as a passenger with Joseph in a Cessna. Other inspiration includes programs about "cutting edge technology" on the Science and Discovery Channels. He viewed conducting cutting edge research as an opportunity to prepare for an industry job. Cutting

edge technology furthers science, adding to the body of knowledge. This concept was connected to national security and urban reconnaissance:

> [T]here's so much out there that we don't know. I mean we understand how a plane flies so we don't really know how it flies in certain situations through [garbled] environment. And as problems present themselves, you always try to find a solution to it. And now that terrorism has become such a problem, it's become such an urban warfare, there's more of it out in the open. We're looking for better ways to find a surveillance system to inspect [?] terrorism, or crime, or anything that's in an urban environment.

The MAV is "cool" in that the smallest, 3-inch model is "almost like a hummingbird." The fact that something that size is controllable is "cool" and "cutting edge." Yet, aesthetics were a secondary consideration. The smaller ones are "almost a circular heart" in terms of shape, but that is to provide lift at small scales.

Lewis felt qualitative analysis is quite valuable. Being an RC pilot helps the researcher to understand how MAVs react in certain situations, and design accordingly. In terms of creativity, he felt that the researcher can be as creative as he wants to be so long as the MAV flies at the end of the day. He was initially hesitant to call MAV research an art:

> I don't know if you'd say art. Actually, yeah, you know there is an art. Because they're small in scale, you have to be skilled in how you design if you want it to fly correctly. . . . You have to be careful. You have to be skilled. You can't just stick a flat wing on a small MAV and expect it to fly. You have to understand the background of it. And being that small, you can't have the large error and expect it to fly. Everything has to be precise.

Lewis aspired to attend MAV competitions. As an undergraduate senior, he participated in the AIAA Design Build Fly (DBF) competition. His team did not win, but he felt it was worth it to see how other teams design. He viewed it as a learning experience.

In order to get to the MAV competitions, he felt he would have to “wedge” himself in to Dr. Peterson’s lab, because “there’s so many guys that work in that lab and want to go.” Micro Air Vehicle competitions are good for building “camaraderie,” and as a “learning experience.” The researchers discuss their work and “collaborate” at conferences. Though full of pressures, such conferences are his most memorable experiences so far of engineering research, for the contacts he made and the travel.

In terms of communication, he did not find it necessary to communicate with other labs. His area of research in flight dynamics is very specific. He noted, however, that he just has not gotten to the stage in his research that requires wind tunnel testing, or he would spend more time there. He visits friends in the other MAV lab to get an idea of how to design his “platform,” as well as his sweeping wings.

The morphing wing lab was recently inundated with journalists calling for interviews. These were mainly film crews that came to film the MAVs for technical shows. Most of the shows are still in production, so he has only seen a couple. Lewis was not interviewed. He had confidence in the competence of the reporters, however, because they represented technology shows on the Science and Discovery channels. Thus, his lab became the subject of the very documentaries that inspire him. As conference papers are the primary method of communication for the lab, generating popular interest through the press is “the cherry on top of the cake. It’s a bonus for us.”

On the other hand, Lewis felt everyday people he meets may not understand what he does initially, but they’re “definitely enthralled.” His family is supportive of his chosen career path, however, he is the only engineer in the family so their understanding

is naturally limited. He felt “lucky” in his job, in that he gets to be involved with cutting edge research and that he gets to do his “passion.”

A typical research day involves getting up early, going to school, and playing with some code. Lewis then goes down to the MAV lab to fabricate. After this, he returns upstairs to model MAV dynamics on the computer. If he and his teammates are “lucky” they get to flight test the MAVs.

The design process begins with looking at existing models of MAVs that could already solve their problem. If no solution exists, they improvise. The team then flight tests the prototype with sensors, such as gyros and accelerometers, and compares the data to their model. If it works, they design a controller. If not, they must change their model in what amounts to an “iterative” process, essentially, trial and error. The atmosphere is casual among labs. Members never hesitate to share information.

Lewis’ approach to research has also changed. He no longer dives in head first, but adopts a calculated approach. Design obstacles include getting everyone “on the same page,” deadlines and schedules. Everyone is trying to get his ideas down, and there is “always a communication barrier.” Changing research parameters is always a challenge. However, this aids design novelty.

Goals for MAV research are mainly for defense. Lewis mentioned police surveillance, reconnaissance of gang violence, wildlife conservation, and hurricane relief. One big goal was to save military scouts from dying in a bomb blast. This was “taking the human life out of” the process of bomb detection. Lewis notes that the government is the “biggest perpetuator” of MAV research.

Lewis primarily enjoys the outdoors, including hunting, fishing, and flying RC aircraft. In fact, he is a "monster truck enthusiast." He likes to drive four wheelers, and owns a "big, jacked-up truck" that he takes to local speedways. He attributes his initial motivation to get involved with cars and planes to off road driving—you have to know how to fix cars. Experience working on cars also makes it easier to come up with "conceptual designs" for MAV parts.

Studying off-road vehicles is his side project. His goal is to create a "smart suspension system" for a car that can accommodate different terrains, in much the same way that the MAV can morph to fly in various conditions. However, although there are "control similarities," the two systems are not very similar, as "one flies and one drives."

To Lewis, "research ethics" implied not stealing research. When I probed about the ethics of conducting military research, he asked if I was "talking about something that might kill somebody some day." He had not really thought about that aspect in terms of ethics. He found nothing unethical about designing a surveillance aircraft, because it would be used to benefit his country, adding, "I think."

Lewis noted a positive effect on his communication skills as a result of his involvement with MAVs. Making many presentations honed his visual communication skills, and allowed him to emerge from of his shell. He registered an increase in success in certain aspects of life.

Lewis: Structural Description

Lewis was (1) not an airplane enthusiast until he got into college and began meeting members of the MAV lab. His inspiration for MAV research comes from observing birds. He is native to Gainesville and enjoys the outdoors, but does not relate this to his study of MAVs. Lewis (2) does not seem to view nature as a subset of

technology. Rather, the agility of birds represents a model to anticipate ambient conditions for MAVs.

Lewis also draws inspiration from the need to develop urban reconnaissance. He openly acknowledged that the military is the biggest "perpetuator" of research. He mentioned police surveillance, monitoring gang violence, and hurricane relief as applications. Inherent in his research is an understanding of the (3) urgency for developing a new kind of surveillance to combat terrorism.

Flying is Lewis' "passion." He spoke of the "freedom" of flight. He felt "lucky" to be involved in the "cutting edge" MAV research. He felt "lucky" when they actually get to test fly the MAVs. Lewis has a love of flight, and as a result he has a (4) sense of privilege regarding his research. This privilege also has to do with conducting "cutting edge" research, another source of inspiration. Cutting edge research furthers science. There is an implicit desire to push boundaries of nature and science through his research.

Another example of this desire to push boundaries follows from his description of the MAV as "cool." It is cool because it is small and yet very controllable, and therefore it is also cutting edge. He acknowledged (5) an aesthetic of coolness. Yet aesthetics and creative expression are secondary considerations. For Lewis, (6) practical, functional considerations are paramount. However, he (7) acknowledged the importance of qualitative analysis in design. He felt that MAV research (8) could be seen as an "art" in that design must be "precise."

Lewis has not been to competitions, but aspires to. He viewed them as a "learning experience," and a place for "collaboration" and "camaraderie." He would like to go to see how other teams design MAVs. As such, he (9) viewed the competitions more as a

means to open channels of communication. However, he noted fierce competition to become an inside member of the UF MAV team.

Lewis (10) did not place much emphasis on internal communication between labs working on MAV research. However, he noted that some of this is circumstantial, as he had not had a chance to get to the wind tunnel testing phase of his research yet. He also looked to other labs for advice on how to design for platforms. He described the atmosphere in the labs as laid back and casual. People joked around. Lewis had been the victim of Joseph's rubber chicken escapades. As such, he and other lab mates initiated a campaign of retaliation that involved killing the chicken in various dioramas.

Thus, it would appear that (11) MAV research involves some interdisciplinary interaction. As a newer lab member, perhaps Lewis preferred to concentrate more on the task at hand. He also noted that communication problems are central to research, in terms of getting everyone on the same page, and getting all ideas out on the table. A central problem in the lab involved (12) management of competing ideas. Lewis also described the (13) design process as "iterative," in the sense of being trial and error. As a result, his approach to research has become more methodological.

Communication with the press is good, especially for the morphing wing lab, which attracted well-informed niche reporters. Lewis felt (14) communication with the press was fruitful, if only a "bonus." Interestingly, the very programs that inspire him to do research actually covered his laboratory.

In his opinion, the (15) average person may not understand the research, but they are "enthralled." He reports (16) positive effects on his communication skills as a result

of his involvement in MAV lab, particularly in terms of visual communication. He also reported (17) feelings of success.

Lewis conceived of “research ethics” as not stealing results from other people. There is again the (18) tendency to play up defense-related applications, and disinterest in ethical questions surrounding military research. Interestingly, he noted that the goal of MAV research was “taking the human out of” the bomb detection loop. The notion of (19) removing the human element for safety and efficiency underlies his research.

Finally, Lewis enjoys the outdoors. This includes off road cars and monster trucks. Like other MAV researchers, Lewis (20) took interest in negotiating physical extremes. In his case, it is the off road terrain. The interest in the terrain, however, also inspired him to become more mechanical by working on cars, which aids in designing MAV parts.

There is a (21) correspondence between the two systems he investigates. Mechanical competence involving automobiles enhances mechanical competence with MAVs. Also, both the suspension system for the car and the morphing system for the MAV are control systems that must adapt to their environment. However, these parallels break down because he views them as two distinct systems for different environments.

Essential Description

Micro Air Vehicle Researchers: Background and Personal Experience

Recall that, as a constructivist study, generalities are not the central aim of this phenomenology. Instead, this research emphasizes accurate description of the lived experience of MAV researchers. The MAV researchers interviewed for my study range in age from their early 20’s to mid 40’s, and include a mix of professors and students. Micro Air Vehicle research draws together a diverse group of engineers from aerospace,

mechanical engineering, and machine vision. Their length of involvement with the project ranges from 1.5 to 8 years.

Researchers become involved with MAV research by meeting present members of the laboratory in classes or at conferences. Some segued into the lab by way of a related engineering field. There is a feeling of having “lucked” in to the research. Others have been directly involved with planes their whole lives. They held a childhood fascination with flight. They grew up around planes, have relatives who fly, and are themselves trained pilots and RC enthusiasts.

Extreme sports play a role in MAV researchers’ lives. Co-researchers are skilled pilots, or compete in RC championships. Others mountain bike or drive off-road. The emphasis on extreme sports manifests a parallel interest in pushing physical extremes that is complimentary to the process of MAV research.

A typical day for a MAV researcher is highly regimented. Professors spend their days advising students on various projects. Students code software, discuss design challenges, and fabricate MAVs. There is a large social component to the research that involves loafing and shooting the breeze before getting down to work. The laid back atmosphere is conducive to communication, which invariably centers on the research. The social element of MAV research attests to this discursive quality of the research process. Even competitions are designed to advance communication between universities (of course, there is fierce competition within the UF MAV lab to go to competitions). However, there can be problems involving communication within the MAV labs. One lab might not know what the other is doing, the result of over-specialization in what amounts to a myopic approach to research.

Family and friends are supportive of MAV research, but lack the background to fully appreciate what their loved ones are doing. Winning at international competitions, however, is a feat that everyone can understand. As such, family and friends of MAV researchers focus their pride on the success of the MAV researchers at international competitions.

Researchers see MAV technology as obscure. They anticipate people outside the lab being scared off initially by its complexities in everyday conversations. Conversations between MAV researchers and non-experts are kept on a surface level. Researchers express frustration that non-experts view MAVs as toys, with no appreciation for the complexities of the research. Still, once the idea of an MAV is introduced, non-experts are enthralled. The MAV is cool. It is a captivating and intriguing concept.

Communicating with the press is a secondary concern, though the coverage is welcome. Micro Air Vehicle researchers feel that the press requires rudimentary, highly visual explanations of MAV research.

Researchers gauge a positive impact on their self-esteem as a result of involvement with the MAV project. They achieve recognition, are able to travel and meet many people, and expand into adjacent areas of research. There is a sense of pride and privilege in being able to work on cutting edge technology. Micro Air Vehicle researchers also describe an enhanced ability to communicate, particularly in terms of visual images intended to analogize their research for journalists and non-experts.

Micro Air Vehicle engineers are a very competitive group of people. They elaborate details of competition, and are very proud of being at the cutting edge of

research. There is a strong desire to be able to be the first to take steps in a field, and conduct novel research. As such, they are critical when other designs for MAVs are not practical. However, competition has the flipside of promoting communication between schools as noted.

Micro Air Vehicle researchers also have a non-conformist streak, defining themselves in opposition to conventional careers. However, they still think about their research from a career standpoint, and the switch to MAV research is viewed as a good career move.

Motivation, Inspiration and Goals

Micro Air Vehicle researchers described themselves as “fascinated by,” “obsessed with,” and “in love with” MAV research. They are passionate about their research. They are thankful for the opportunity to do cutting edge research, and doubly so because MAV design is an academic problem with real world implications.

A sense of privilege pervades the MAV researchers. Members feel lucky to be included in the work and have the opportunity to work on something cutting edge. The opportunity to be a vanguard in an engineering field is rare. Micro Air Vehicle researchers feel privilege in terms of being able to operate a small aircraft that few people get to fly. As such, many exhibit a preference for being able to test fly the MAVs.

The research is revolutionary, groundbreaking and exciting. Inspiration stems from facing open barriers for research that require paradigmatic design shifts. Researchers also draw inspiration from nature, and areas of engineering outside of aerodynamics.

Micro Air Vehicle researchers refer to design challenges, one of the most prominent of which is changing design parameters to probe open barriers of physical and mathematical boundaries. The motivations to meet these challenges are largely

pragmatic. Researchers exhibit preference for tangible, verifiable results due to military funding. The concrete parameters imposed by the military funding expedite research because they provide a time limit and set of constraints on the MAV designs.

Miniaturization is another important goal of research. Researchers repeatedly refer to the goal of making “smaller and smaller” designs. The drive to condense all MAV functionality into a “smaller and smaller” package is a corollary to the underlying drive to push physical boundaries.

Micro Air Vehicle research addresses the urgent need to develop surveillance technology to combat terrorism. A related goal is to remove humans from dangerous situations, such as bomb detection in a war. This is achieved by increasing MAV autonomy.

Micro Air Vehicle engineers also wish to produce generally applicable research that pushes boundaries of science. They want to contribute to the overall body of scientific knowledge. This involves attempts to leverage design on multiple levels, keeping simultaneous applications in mind.

Novelty is another frequently mentioned aspect of research. Novelty implied cutting edge research, which required ingenuity. Finally, the researchers wanted to create technology that was aesthetically and functionally “cool.” For them this meant ultra-lightweight materials, maneuverability, pushing boundaries, and futuristic lines.

There is no reason to leave the MAV lab from a career standpoint. There is ample funding for research, and members have the freedom to explore their own ideas. Finally, there is a sense of privilege in that the MAVs are at a perfect scale for research. Because their small size precludes on-board pilots, no IRB clearance is necessary for this kind of

research. Indeed, many designs require no pilot at all, on-board or remote. Rapid iterations can be run, and thus there is great potential for explosive advancement.

Design Process

The design process was frequently described as iterative. This implied computer modeling, building models, running tests, and comparing the data to the initial simulations. Iteration is a methodologically exhaustive and algorithmic. Essentially, it is trial and error. It can be frustrating if it comes to a dead end, which it frequently does, because the process is so pain staking and time consuming. However, iteration also implies a balancing act of optimization, as the overall integration of systems is relaxed into equilibrium. This evokes the interrelatedness of the MAV research and labs themselves.

There is a strong interdisciplinary component to the MAV research. Because the MAV is small and portable, it allows the researcher to have involvement with every aspect of design. Researchers stressed lots of visiting between labs. Professors collaborated on various problems. Thus, MAV research is highly discursive. The researchers tend to be very social. Even competitions were sights of camaraderie and discussion.

The interdisciplinary nature of MAV research also stems from the ability of researchers to draw inspiration from a variety of sources. This included the ability to take inspiration directly from nature, as well as see symmetries between MAV research and other forms of engineering.

This frequently implied expressing systems in terms of pure mathematics, as control systems. Abstraction of the problem transcends physical differences through mathematics. In some instances, this elevated the research to a purely mathematical

form, rendering the applications nearly irrelevant. For the most part, however, parallels between systems were only surface level analogies intended to convey research.

Qualitative analysis plays a prominent role in design. Many of the engineers in the lab were surprised by the amount of qualitative analysis involved in MAV research. They respected the role of qualitative analysis immensely. Qualitative analysis demonstrated how MAV research was in a way an art, because it is subjective, yet precise. RC pilots verify designs through flight. Because of their experience, pilots have a realistic edge in understanding how a MAV handles, and how it should be designed. Qualitative analysis was useful, but always secondary to computational analysis.

Biology provides inspiration for MAVs. The MAV researchers view biology as a subset of technology, and to ratiocinate animals into subsystems. They stand in awe of the complexity of nature, and almost seem to be in competition with it. However, another key belief among the researchers is that, although nature was way ahead in many aspects of MAV flight, as humans we have access to an alternative design space—for example, incorporating rotary mechanisms into MAVs. Nature makes little to no use of rotating parts. Therefore, in some respects humans can design with greater intelligence than nature itself.

Finally, a practical attitude pervaded the design process. Researchers thought in terms of efficiency. This manifested in their emphasis on miniaturization, removing humans from the control loop, and streamlining the design process for rapid fabrication. Military funding definitely played a role in influencing this results oriented attitude.

Micro Air Vehicle as Research Object

Just like lay people, MAV researchers themselves have a tendency to be drawn in by the coolness or cutting edge nature of MAV design. All co-researchers use “cool” to

describe MAVs. It has various implications, including the materials used, which are lightweight and strong, the unusual shape, which is due to small scale aerodynamics, the cutting edge nature or novelty of the research, and the fact that MAVs push physical extremes. Their UFO-like contours evoke the alien quality of these extremes. Micro Air Vehicles are also “cool” in that they have popular appeal. Cool looks may impact design, but aesthetics are secondary considerations due to geometric constraints. Fortunately, something that has eye appeal usually flies better, too.

Researchers tend to acknowledge the military applications of MAVs openly. Some are proud. They acknowledge that military funding is the primary source for their projects. In many cases this expedites research. However, they all stressed defense and surveillance applications for MAVs, and the strategic benefits offered by MAVs to the soldier in the field. Micro Air Vehicle research is fundamentally a defense technology.

The foremost application mentioned was saving lives on the battlefield, particularly during bomb assessment. Researchers also stressed the utility of MAVs in conducting urban reconnaissance, either in a war, or for law enforcement. Gangs, drug traffickers, and terrorists were targets. This especially shows how the war on terrorism underlies emphasis on surveillance. Next, researchers noted search and rescue applications, such as hurricane relief, and wild life conservation (which could also save human lives from death by airplane crash).

Thus, one idea embodied in the figure of the MAV was removing the human from the control loop, and thereby, from harm’s way. This idea was echoed from the vision systems, which ran “hardware in the loop” simulations, all the way up to fabrication.

Underlying this was the assumption that MAVs could do jobs more efficiently than humans, but the essential point being that MAVs could place people out of harm's way.

Since they view MAVs as defensive technology, the researchers exhibited initial confusion as to whether the term "research ethics" referred to stealing research, or conducting military research. Most had not considered the ethics of doing research for the military. However, they exhibited awareness of an ethical component to developing military technology. Micro Air Vehicle researchers did not seem concerned about the ethics of MAV technology. Ethics was something relegated to the area of bioethics.

The government was seen as an enabler. Researchers were candid about military funding, but seemed hesitant and even a little nervous when discussing potential offensive applications of MAVs. Again, this was because the MAV researchers viewed MAVs as surveillance technology intended for defensive purposes to save lives. Ethics of conducting military research remained an uncomfortable topic, characterized by disinterest, slight nervousness, and some hesitance to discuss.

The groundbreaking nature of MAV research stands in stark contrast to the "toy-like" qualities ascribed to them by lay people. Micro Air Vehicle researchers felt that lay people frequently mistook MAVs for toys. They could not appreciate the complexities of MAV research. Indeed, without the control system a MAV is just a toy. The beauty of a MAV is not only that it is small and durable, but that it also has autonomous capabilities. Friends and family tease researchers, observing that they are just playing with tiny planes all day. The unimposing figure of the MAV stands in stark contrast to its implications for search and rescue, security and surveillance.

Interestingly, MAV researchers mainly view science fiction as a form of entertainment. However, they described MAVs in futuristic terms that estranged the researcher from the MAV, such as "flying saucer." Researchers thought of MAVs in terms of science fiction-like future scenarios, for example, by envisioning MAV swarms, or a time when MAVs are ubiquitous for surveillance, or a future battlefield of warring robots, devoid of human soldiers.

Creativity and Micro Air Vehicle Research

Creativity manifests in several notable ways in the MAV labs. First, there is a belief among researchers that MAV research has an artistic component. This is associated with qualitative analysis. Trained pilots in the lab must fly MAVs to verify response. Micro Air Vehicles are an art in that they must be precise, and yet subjective analysis is required to function. The trained pilots in the labs analyze data and design with their own subjective criteria in mind. This is always secondary to quantitative analysis, however.

Secondly, creativity manifests in the MAV researchers' drive to generate novel designs. Novelty is a key motivation for MAV research, both because the researchers are on the cutting edge of their field, and also because novel designs garner greater profits in the long run when they attempt to market the designs to industry.

Part of what fuels this novelty is the imposition of design constraints. These constraints come from the MAV competitions. The endless challenge of design results from constantly switching these design constraints. Researchers need to keep generating novel platforms to accommodate new constraints.

Interestingly, this echoes Boden (1994), who noted that creativity is not merely changing a few words in a sentence to produce a new line. Rather, it is instituting

calculated systemic changes in a set of constraints, like Schoenberg's space of atonal music, or Lobachevsky's formulation of non-Euclidean geometry. Micro Air Vehicle researchers deal with the same sort of historically unprecedented creativity, or "H-creativity," every day by varying design constraints.

In closing, perhaps the pressures of military contracts, deadlines and competitions play similar roles in forcing the researchers to produce under design constraints. Recall that competition is both between schools, and within the lab itself. Intra-lab competitions are sometimes used to support expression of individual design concepts that would not otherwise be brought to the fore.

Member Checks

To ensure accuracy of findings, a copy of individual descriptions, interview transcripts, and the essential description were e-mailed to co-researchers for verification as a form of member checking. So far, there have been no objections to the portrayal of MAV research. It can be assumed with some certainty that the essential structures distilled from the research accurately represent the experience of the MAV researchers who participated in my study.

My sense is that the only way to generate a deeper understanding is to begin to understand the MAVs in terms of control systems and differential equations, and to enumerate components. This would be a purer representation, but it is beyond the scope of my study. To put it another way, from the perspective of the researchers, ultimately the MAVs can only understood mathematically.

Summary of Structures

The following two charts summarize individual structures, with supporting textural and biographical details.

Table 5-1. Summary of Structures: Davison, Peterson, Eric and Mark

Co-Researcher	Davison	Peterson	Eric	Mark
Age/Area of Research	42, machine vision	45, aerospace, lab director	24, aerospace, grad student	26, aerospace, grad student
Length of involvement with project	2 years	8 years	2 years	3 years
Aesthetics and Coolness	Aesthetics are not great concern; "Cool" looks impact design; cool implies in "technical, geeky way", popular appeal	Cool in that MAVs are "fascinating"; cool connected to wind-surfing	Cool in terms of pushing physical boundaries	Cool is anything made out of carbon fiber, in that it is lightweight but strong
Applications	Noted military apps; stressed conservation, search and rescue, defense	Play up civilian applications, downplay military; uncomfortable topic	"99%" are surveillance; fundamentally defensive technology	Wildlife conservation; removing people from battlefield; emphasize defense
Communication: family, friends, within lab, strangers, press	—	Obscure technology; people view as "cool," envision world where they are ubiquitous	Difficulty communicating with career-minded people, keeps it "on the surface"; family, friends tease about being perpetual student	Communal, social element to MAV research; not many people aware of research within larger University community
Competitive drive	Pioneering math	Elaborated on competition	Strong will to take first steps in field; no interest in MAV competitions	Desire to be the first to come up with solutions
Design Inspiration	Facing "open boundaries" that are mathematical; Mathematics transcends physical differences between systems	MAVs are "fascinating"; Pioneering research; initial inspiration is windsurfing; Biological inspiration is important; design space "not accessible to nature"; nature as subset of tech.	MAVs are "revolutionary," "ground breaking" and "exciting; generating cutting edge research	Speaks in terms of loving his work; some science fiction; Acknowledges artistic component to research; creativity centers on creating novel ideas; "Interest and love" is new problems

Table 5-1. Continued

Co-researcher	Davison	Peterson	Eric	Mark
Ethics of military research	"100% control" over ethics; new research has few precedents	Ethics implies "bio-ethics"	Government as enablers; ethics relegated to biology	Candid about military funding; nervous laughter?
Interdisciplinary nature of research	—	Lab coordinator; varied advisees; collaboration w/ other professors on MAV vision	Inhabits up to 6 labs at once; initially attracted to lab for this reason; enjoys communication with a variety of people	Related to iterative design process; also communal, social element to laboratories; time spent in wind tunnel
Initial involvement in project	Segued into vision control	Thought it was a "fascinating" topic; inspired by wind-surfing	"Lucked" into research; planes have grown on him; initial interest in wing structure	Childhood fascination; trained pilot; RC experience
Miniaturization	Object oriented approach	Goal to put all MAV "functionality" on single chip	N/A	Making things "smaller and smaller"
Motivation	Push boundaries; produce generally applicable research	Remove human from equation; increase efficiency	Pushing boundaries, making something cool; remove human from control loop; machines more accurate	Streamlining design process for rapid iteration
Novelty	—	—	Opportunity to be vanguard in field; unconventional line of work	Creativity centers on creating novel ideas
Privilege	—	—	MAVs are "cutting edge"; rare to make first step in field; novel research; refuses to see self in common place job	"Every day is Christmas."
Pushing boundaries and pioneering research	Facing "open boundaries" that are mathematical	Seeks previously unattainable "flight regime," extreme experience physical world	Source of motivation; pushing physical limits	Streamlining design process and miniaturization

Table 5-2. Summary of Structures: William, Steve, Joseph and Lewis

Co-Researcher	William	Steve	Joseph	Lewis
Age/Area of Research	24, aerospace	35, aerospace, MAV fabrication lab director	24, aerospace, grad student	22, aerospace, undergraduate
Length of involvement with project	3 years	5 years at UF; 5 years in Korea	8 years	1.5 years
Aesthetics and Coolness	Aesthetically, carbon fiber looks cool	Attractive airplanes fly better; competition rules too restraining, circular shape is not optimal	Aesthetics are secondary considerations due to geometric constraints	Small, yet very controllable; “cutting edge”; aesthetics secondary to functionality
Applications	Surveillance apps. And strategic benefit to soldier in battlefield	Surveillance, including wildlife and crawling MAV	Stressed defense applications; wildlife conservation, law enforcement, insurance	Combating terrorism; urban reconnaissance
Communication: family, friends, within lab, strangers, press	Both parents pilots are intrigued with research; frustration communicating to lay people	MAVs are obscure; most encouragement from family, friends comes for competitions	Lab researchers too myopic, preoccupied with making their contribution key; non-experts have “rudimentary,” “visual” understanding	Feels visual communication skills have improved since joining MAV lab; average person may not understand but are enthralled
Competitive drive	Participated in all three competitions; foster communication; MAV team is very competitive; grudge with MIT	Attended all competitions since 2000; openly competitive; hopes it facilitates research; competition rules too restrictive	Attends competition four years as pilot; recalls pressure of being a pilot; competition with nature, though reverence for god and nature	Plans to attend competitions; competitions as opportunity to develop camaraderie; competition within MAV labs to attend
Design inspiration	MAVs are “cutting edge”; never done before; academic problem, real world implications; biological inspiration is dragonfly	Scales require different “physical philosophy”; working on something that no one else has before; competition with nature	“Obsessed with” morphing wing; work is “fun”; “obsessed with” Transformers; photography is “hopeless passion”; popular culture; drifting	Photographs of birds; “passion of flight,” “freedom” of flight; technology documentaries

Table 5-2. Continued

Co-researcher	William	Steve	Joseph	Lewis
Ethics of military research	Awareness of ethical component, but not a concern, “Pays my paycheck”; no DARPA funding, MAV lab is second tier	Not shy about military funding; better than pure academic research because requires results; slightly nervous to discuss	Canadian born, father Syrian, devout Muslim; acknowledges conflict of interest; reiterated interest in pure research	Hopes that government will not use MAVs for offensive purposes; had not fully considered this idea
Interdisciplinary nature of research	—	MAV research allows you to work on every part of aircraft	Controls person, but likes to build, too; ability to see various systems equivalently w/ mathematics	Not paramount, but still new to research; bounces design ideas off colleagues
Initial involvement in project	Inspired by parents to become pilot; involved in RC whole life; trained pilot; career path affected by 9/11	25 years in field; trained pilot and RC enthusiast; 2000 MAV competition at UF	Studied Magnus effect inspired by Golf game	Interest in MAVs developed in college; parallel interest in cars developed
Miniaturization	Pushing boundary of size is key inspiration	Not as important	MAVs are at perfect scale for experimentation	—
Motivation	Reducing scale and fabrication time; making MAVs resilient; pragmatic design	More interested in larger MAVs for practical purposes; preference for tangible results; military funding more productive	Morphing wing “embodies” professional goals, “microcosm” of career	Develop new generation of surveillance technology; national security; taking the human out for safety and efficiency
Novelty	One of the few people able to fly MAV scale planes	Inspired by novelty of research; approaching problems in novel ways	Sense of privilege to do novel research	Cutting edge research that has never been done before
Privilege	Humility, not all people raised around planes; one of the few in world to fly MAV scale planes	—	Scale of MAVs is perfect for research	Feels lucky to be able to work on cutting edge research; lucky when they fly
Pushing boundaries and pioneering research	Pushing boundaries of scale is key motivating factor	Motivated by government deadlines	Pushing physical boundaries through sports as through research	In sense of conducting novel research, designing at new scales

CHAPTER 6
CONCLUSIONS

Summary

According to Meloy (1994), a qualitative study only comes into focus at the end of the research process. Research questions are not evident a priori, due to the nature of qualitative research. Meloy suggested equivalence between the end and the beginning of a qualitative study, calling into question the linearity of the research process. She questioned whether the structure is merely a formality of traditional academic research. Perhaps this lends itself to future, web-based texts as yet not conceived.

Non-linearity is especially apparent in the case of phenomenology, where structures emerge as synergistic perceptions. During the construction of the essential description, elucidating structures of the lived experience of MAV researchers became an almost tactile distillation—a sifting through and drawing out of contours.

The following summary presents key findings of the original research focus. This focus called for the essential description of lived experience of MAV research, an explanation of why researchers chose their line of work, description of the MAV as "research object," and elucidation of the creative processes at work in the MAV laboratories.

Essential Description and Choice of Micro Air Vehicle Research

Phenomenologists have been skeptical of applying phenomenology to technology on a case level basis. Phenomenology and technological ethics have also received a chilly reception in America. My study testifies to application of phenomenology on a

case-by-case basis, as Knopf (2004) put it, essence versus Essence. My study yields insights into the perceptions, creative impulses and philosophies underlying an emergent technology that is also relevant to the modern political climate. As opposed to developing grand theory (Essence), this scaled down form of phenomenology allowed me to investigate a single topic in detail. This is a more pragmatic, constructivist approach yielding a more accurate picture of the phenomenon because of the emphasis on contextualized observations.

The essential description provides a window into the everyday world of the eight engineers who graciously participated in my study. These engineers either came to the research from fields related to aerospace (such as mechanical engineering or mathematics), or have been flying airplanes or RC aircraft since they were children. The MAV researchers are disciplined, highly competitive people motivated by the prospect of conducting novel, cutting edge research. They define “cutting edge” as research that requires novel approaches, and has never been attempted before. Cutting edge research also implies pure science with real-world implications. Finally, MAV engineers describe their research as “cool” in the sense that it is cutting edge, resilient, and futuristic.

Micro Air Vehicle researchers are pioneers in their field who push boundaries, whether those boundaries are abstract computer algorithms or physical limitations on mechanical systems. Researchers consistently referred to pushing boundaries—of physics, of scale, of previous research—as an underlying motivation for their research. For example, the MAV researchers repeatedly referred to making things “smaller and smaller” as core motivation. Thus, in terms of their approach to design philosophy, MAV researchers confirmed the modern connotation of technology, in the sense of

applied science. This definition emerged over the centuries from Aristotle's original term, techne, and echoes Heidegger's transhuman interpretation of technology as research for research's sake.

Furthermore, because MAV researchers view the technology fundamentally as surveillance they envision a wide range of applications, present and future, which expand human perception. Micro Air Vehicle researchers view technology as organic extensions of man, rather than adopting a transhuman view of technology as "human veneer" (Mitcham, 2005; p. 574). Yet pushing boundaries is an underlying motivation of research. It is interesting that there should exist this dualism of applications as extensions, yet the underlying motivation is transhuman. In the case of MAV research, this view of technology was not as stark as Heidegger made it out to be. The researchers cracked jokes, and undercut their sense of privilege with a self-consciousness and sense of humility.

In terms of lab socialization, MAV researchers report segmentation, differentiation, or specialization to accomplish tasks in the lab. However, this is also a problem, in that there is not enough communication between labs because everyone is preoccupied with his own projects. Overall, the researchers place a high value on communication within the laboratories. Micro Air Vehicle researchers are passionate about their work in the extreme, and perceive an aesthetic to their research that transcends quantitative analysis. They even go so far as to call MAV research an art form in that it relies on subjective impressions. The need to negotiate research parameters underscores the importance of discourse in MAV research.

Communication with non-experts is of secondary importance. Friends and family are generally supportive of MAV researchers, but communication with non-experts is a source of frustration. Non-experts have a difficult time appreciating the nuances of the MAVs, and tend to trivialize the research from the perspective of the engineers.

Researchers could not emphasize enough the defense applications of MAVs. From their perspective, the MAV is surveillance technology intended to save lives by removing people from dangerous situations. As a result, researchers had a difficult time comprehending the relevance of ethics to their research. "Research ethics" was seen an academic problem—a question of stealing research. Some respondents left it at that. Others wondered if I was intimating something about the ethics of making weapons.

The general consensus among MAV engineers is that the MAV is a defensive surveillance technology. There is no discrepancy between law enforcement and military applications on the one hand, and civilian and conservation applications on the other. These are all forms of surveillance technology intended to save lives. The technology is not a double-edged sword. Researchers feel that they have power to leverage uses of the MAVs.

The MAV appeared as an emblem of the War on Terror in a post-9/11 world. Micro Air Vehicle researchers perceived the MAV as surveillance technology, but first and foremost a surveillance technology to catch terrorists, and for urban reconnaissance. True to DARPA roots, researchers perceive the MAV as a new form of technology key to the shifting terrain of 21st century warfare.

However, it is important to note the absence of a significant political dimension in the MAV engineers' rhetoric. There was disinterest in and reluctance to discuss

offensive applications. The general hope among researchers was that the military would not use MAVs for offensive purposes. The lack of interest in ethical aspects of military research suggested deferment to public policy makers on issues of regulation.

References to *Minority Report* (2002) and Transformers suggest influence from science fiction and popular culture on the MAV designs. Science fiction and popular culture are sites for public discussion of technology (Lambourne, 1999). While in general MAV researchers view science fiction as mere entertainment, all of the MAV researchers referred to the MAVs as "cool" in the sense of being cutting edge and futuristic. They tended to view the MAVs in futuristic terms, and imagine futuristic scenarios.

Micro Air Vehicle as Research Object

Bucciarelli (1994) defined the "object world" of an engineer as the materials, concepts, and language of the researcher's universe (pp. 65-69). Many aspects of this object world were ephemera in the design process that vanished undocumented along the way to a final "research object." A "research object" is a way of seeing technology as an artifact that is the sum of negotiation within the culture of the engineering laboratory (Bucciarelli, 2002; pp. 219-231).

The object world of the MAV researcher consisted of many such intermediate steps along the way to the final "research object"—from the small programs written to run simulations on various parts of the MAV, to the ultra-strong sheets of carbon fiber shaped as the skin of the MAV. It is interesting to note that the design process itself became an "object" to be streamlined for rapid iteration. As Bucciarelli (1994) suggested, a management process itself can be a kind of laboratory "object" on the way to a finished product.

Finally, the area of qualitative analysis is the biggest reminder of the nebulous "object world" of the engineer in the case of MAV research. Qualitative analysis is a subjective call on the part of seasoned pilots. There is no formal record of this stage in the MAV process, yet every MAV researcher mentioned that it was an important part of design.

Creativity

Contrary to the belief that serendipity is random, much of the work done in the MAV labs consisted of trial and error iteration, and was performed in hyper-segmented teams. This verifies Dunbar's (1997) suggestion that scientific reasoning is frequently "distributed reasoning" (pp. 487, 488), i.e., that scientists frequently make discoveries in groups as opposed to having personal eureka moments. Moreover, researchers were aware of what inspired them and actively sought out these activities, such as photography, nature watching, and extreme sports. Perhaps these represent some "Klondike spaces" hinted at by Perkins (1994, p. 7).

Analogy also had a role in the MAV labs. These were not analogies in the sense of visual images, but rather of a highly technical nature. The analogies took the form of algorithms, called control systems. This is in keeping with Dunbar's (1997) conclusion that scientists infrequently make use of analogies outside of their fields when making important discoveries.

Micro Air Vehicle researchers continually change design constraints. This is partially required by military contractors, partially self-imposed, and evokes Boden's (1994) notion of creativity as the implementation of "transformational heuristics" onto problems in order to achieve a goal (pp. 86-91). This is not merely changing a few aspects of a particular solution, but rather engendering systemic changes to sets of

constraints. It is altering the very system of logic by which a problem is defined and approached. This, according to one researcher, is the "never-ending challenge of design."

Limitations

One of the major limitations of the study is also one of its strengths. The research unfolded over the course of two years, allowing sufficient time to build rapport with co-researchers. However, perspectives and people change over a protracted period of time. For example, in two years two major contributors left the project, one moving on to Carnegie Mellon's Robotics Institute, and the other distancing himself from the MAV lab. Several students graduated and left the lab to work for private companies. Also, the emphasis of the research shifted. The machine vision team's emphasis shifted from the horizon tracking algorithms to an object-oriented system. Micro Air Vehicle research is a project with an almost ten year history at UF. The findings of my study can only invoke a narrow window into one stage of an ongoing process.

A further question arises regarding purposive sampling. The sampling method for my study was quasi-random, but predominantly snowball sampling. By contacting racially and ethnically diverse MAV researchers of different ages and varying expertise, every attempt was made to draw from a diversity of perspectives. However, gender presented a limitation because there were no female MAV engineers. Furthermore, none of the co-researchers raised the issue of gender in the course of the interviews. As suggested by Stanley and Slatterly (2003), the absence any discussion of the role of gender in the engineering laboratory suggests that gender is a fertile topic for future inquiry.

Finally, there was the fundamental problem of bracketing. As stated previously, initial rapport-building interviews were conducted with two participants as part of a

previous series of journalistic articles. These were conducted before IRB approval. No data from these interviews was used in this paper. This presents a conflict of interest, in that phenomenology is built on the premise of bracketing preconceptions, so that co-researchers do not feel inhibited. Two of the co-researchers were aware of some of the researcher's preconceptions from preliminary interviews in which the process of bracketing had not already taken place.

Obviously, this taints the data, especially considering that one of the preliminary interviews was the main contact person, Dr. Peterson. In particular, certain critical dispositions and fears about the ethics of military applications were made initially apparent on the part of the researcher. This trepidation came out in the course of questioning which had not yet been properly bracketed. There are two potential saving graces for this otherwise disastrous scenario.

Number one, as experts in the field, the co-researchers did not seem particularly impressed by the researcher's opinions. The co-researchers came off as very confident, though perhaps more hesitant to address military applications than they should have been due to my initial frankness. It makes sense that as elite interviewees they would not be fazed by criticism. In any event, they seemed to register misgivings, but remained open to discussion, particularly Dr. Peterson. Secondly, even Moustakas suggested that it is impossible to relinquish all presupposition in the process of bracketing when he presents Husserl's suppositions of transcendental phenomenology:

> I can intend an open and fresh approach to my knowledge of something but the problem of language and habit still exist; my own rooted ways of perceiving and knowing still enter in. The value of the epoche principle is that it inspires one to examine biases and enhances one's openness even if a perfect and pure state is not achieved…[S]elf-evidence is apodictic[necessarily true or logically certain]…Even if the self is authentically present, a completely free and suppositionless state is

> itself questionable. Self-evidence, regarded as apodictic, is impossible to validate. [Moustakas, 1994; p. 61]

Furthermore, if the researcher is to address co-researchers on an even playing field (and assume reality to be socially constructed) then it might actually have some utility that critical misgivings were initially allowed to bleed through. Of course, it would be optimal to reveal these after all the interviews were completed. Certainly, this is the way the interview protocol evolved over time, eventually relaxing into ten highly general, pared down questions. Still, no researcher can ever be totally free from bias, and since initial critical thoughts inhibited co-researchers in negligible ways, perhaps these actually heightened the robustness of the final data set by highlighting issues and areas of experience that otherwise would not have been broached. My initial lack of restraint remains, however, a serious limitation on the study.

Insights and Future Research

Stanley and Slatterly (2003) concluded that their engineer subjects had blind spots to race and gender issues, preferring instead to speak of science as a lingua franca. Initially, I disagreed with the authors, preferring the idea that engineering can function as an equalizer transcending racial and gender barriers, but now I am not so sure. The only female member of the labs that came up in the research had graduated a few years earlier. She had been a member of the Machine Intelligence Lab, of which the MAV labs are one subset, but never directly involved with MAV research.

Race and gender issues constituted significant holes in this phenomenology. Gender was the most neglected issue. None of the MAV engineers were female. This was never mentioned in the course of the interviews. Future studies might specifically probe the absence of females in MAV research. Other potential topics could include

researchers' perceptions of the ethics of conducting military science. Such a study could probe the whitespace of politics in the engineering lab.

Use of web-based texts is a must for future studies. This includes discussion groups, web logs, e-mail and chat. For example, toward the end of my study I discovered the UF_MAV discussion group on Yahoo Groups, which listed over 200 comments since 2002. Perhaps online discussion could be used as a form of follow-up interviewing, to round out face-to-face interaction. As noted, online interaction has the benefit of not taking place in real time, which means the researcher can multitask, and there is the added bonus of instant transcription.

Mediated communication could become the primary interaction of a phenomenological study. Although more impersonal, the instant transcripts lend themselves to voluminous data. People also interact differently online. The anonymous, impersonal nature of electronic media opens people up. Co-researchers would be more honest in an online environment, especially concerning such hot button topics as gender or politics.

I believe that bracketing is possible and effective, but it requires practice. The process of bracketing my preconceptions about MAV research improved as I progressed through the interviews. My interviewing style became more polished, and I began to relax. My willingness to listen, probe, and experiment with questions increased. I was taking genuine interest in the experiences of another person. If I could begin again, I would be even less opinionated in my line of questioning, focusing less on ethical issues and more on lived experience of co-researchers, the essence of phenomenology.

Conducting phenomenology has improved my ability to divest myself of preconceptions, and be receptive to aspects of people and things in my environment that I might have otherwise overlooked. Phenomenology has also had a positive impact on my ability to communicate perceptions with precision. As Sokolowski (2000) noted, objects, people, and ideas defy accurate representation because they possess so many aspects that it is impossible to articulate them all. However, what is important is to articulate key aspects of phenomena. The mind can have a transcendent, intentional perception of reality based on finite perceptions—a Gestalt.

It was somewhat revelatory for me to understand that there are a discrete number of structures associated with objects, people and ideas. Indeed, this is the essence of journalism—to convey information with brevity, a skill so critical in today's mass media that places emphasis on sound bites. In answer to Meloy's (1994) question of when to end the qualitative study, then, I would say when all of these discrete structures of the phenomenon have been enumerated and articulated.

This phenomenology set out to produce an essential description of the lived experience of Micro Air Vehicle researchers at the University of Florida. A complex picture of the researchers emerged as competitive, but also inspired, artistic individuals. The MAV researchers place high value on social aspects of lab work as an integral component of the creative process. Micro Air Vehicle researchers stress the defense applications of MAVs, and feel that as the architects of the technology they have the power to leverage the eventual outcome of the applications. They are generally disinterested in the issue of the ethics military research because they perceive the MAVs as fundamentally a defensive technology.

Meloy asks if qualitative research is research or stories. I would argue my research consists of stories. To capture reality, phenomenological research aspires to accurately represent the lived experiences of co-researchers. My study began with a warning to Americans to carefully consider the technology that our government is developing. I personally feel that technology in general is not neutral, but rather a reflection of its environment. Initially, MAVs seemed to me to be dangerous technological artifacts reflecting the post-9/11 climate of paranoia in America. To MAV researchers, however, MAV technology is the product of a collective process that is ethically neutral. It does not directly endanger humans in the research process. Furthermore, it is a defensive technology intended to save lives—of soldiers and innocent civilians—and ensure the continued security of our nation. My intention in conducting this study has not been to pass judgment on the co-researchers, but to present their perspectives clearly in their own words—to serve as the conduit through which their stories are told.

APPENDIX A
INFORMED CONSENT DOCUMENTATION

Re: UFIRB #2005-U-1112 (Phenomenology of Micro Air Vehicle Research)

Informed Consent
Protocol Title: Phenomenology of Micro Air Vehicle Research

Please read this consent document carefully before you decide to participate in my study.

Purpose of the research study:

The purpose of this study is conduct phenomenology of Micro Air Vehicle (MAV) research at UF. Phenomenology is concerned with stripping bias to ascertain the "essence" of an object or concept. Phenomenology is used to study abstract concepts, such as ‘love,’ ‘grief,’ or a ‘caring interaction.’ The researcher records preconceptions so as to divest himself of them (bracketing), then conducts interviews to produce objective descriptions of the phenomenon, revealing its essential nature. Finally, the researcher reflects on the findings to check validity. This final stage can include feedback from subjects.

What you will be asked to do in the study:

You will be asked a series of questions regarding your involvement in, and perception of the Micro Air Vehicle research at the University of Florida.

Time required:

1 hour

Risks and Benefits:

No more than minimal risk is associated with this project.

Benefits to you include:

-Opportunity to share your research experience with another person.

Overall social benefits might include:

-Facilitation of communication between journalists and scientists.

-Contribution to the corpus of science communication literature.

Compensation:

There is no monetary compensation for participation in this study.

Confidentiality:

Your identity will be kept confidential to the extent provided by law. As is customary with qualitative research, the names of participants will not be used in publication of the study in a peer-reviewed journal.

Voluntary participation:

Your participation in this study is completely voluntary. There is no penalty for not participating.

Right to withdraw from the study:

You have the right to withdraw from the study at anytime without consequence.

Whom to contact if you have questions about the study:

Mario Rodriguez, Graduate Student, College of Journalism and Communications, UF, (352) 392-6557

Dr. Lisa Duke Cornell, Assistant Professor, Department of Advertising, UF, (352) 392-0447

Whom to contact about your rights as a research participant in the study:

UFIRB Office, Box 112250, University of Florida, Gainesville, FL 32611-2250; ph 392-0433.

Agreement:

I have read the procedure described above. I voluntarily agree to participate in the procedure and I have received a copy of this description.

Participant: _____ Date: _____

Principal Investigator: _____ Date: _____

APPENDIX B
INSTITUTIONAL REVIEW BOARD APPLICATION

UFIRB #2005-U-1112 (Phenomenology of Micro Air Vehicle Research)

UNIVERSITY OF FLORIDA INSTITUTIONAL REVIEW BOARD

1. TITLE OF PROTOCOL:

2. PRINCIPAL INVESTIGATOR(s): (Name, degree, title, dept., address, phone #, e-mail and fax)

Mario Rodriguez

Candidate for Master of Arts, College of Journalism and Communications

1015 SW 9th St., Apt. A4

Gainesville, FL 32601

(941) 284-6054

3. SUPERVISOR (IF PI IS STUDENT): (Name, campus address, phone #, e-mail and fax)

Dr. Lisa Duke Cornell

Associate Professor - Department of Advertising

2074 Weimer
(352) 392-0447
lduke@jou.ufl.edu

4. DATES OF PROPOSED PROTOCOL: From __12/15/05_____ To ___3/15/06_____

5. SOURCE OF FUNDING FOR THE PROTOCOL:
(A copy of your grant proposal must be included with this protocol if DHHS funding is involved.)

N/A

6. SCIENTIFIC PURPOSE OF THE INVESTIGATION:

My goal is to complete a phenomenology of Micro Air Vehicle (MAV) research.

I wish to gain a phenomenological understanding of MAV research from the engineer's perspective, specifically to answer the question, “What is MAV research?”

Potential benefits to society at large include:

-Facilitation of communication between journalists and scientists.

-Contribution to the corpus of science communication literature.

7. DESCRIBE THE RESEARCH METHODOLOGY IN NON-TECHNICAL LANGUAGE. The UFIRB needs to know what will be done with or to the research participant(s).

Phenomenology is concerned with divesting preconceptions to ascertain the "essence" of an object or concept. Phenomenology is used to study abstract concepts, such as 'love,' 'grief,' or a 'caring interaction.' 'Bracketing' in phenomenology allows the researcher to eliminate bias and see the phenomenon through the subject's eyes.

I plan to conduct 5-8 interviews with engineers at UF working on MAVs. Micro Air Vehicles are six-inch and smaller airplanes that could be useful for urban reconnaissance. They are under development at many universities worldwide. At UF, MAV research is being conducted at the College of Engineering under a DARPA contract. The research contact is Dr. Peter Ifju at the Machine Intelligence Laboratory (MIL).

Micro Air Vehicles have other uses beside military applications:

-Search and rescue
-Monitor ecosystems
-Detect biological agents
-Surveillance
-Getting photographs from otherwise impossible vantage points (journalists?)

Because of the nature of qualitative research, and phenomenology in particular, the research questions will evolve over the course of the study. The questions themselves proceed from a very general stance, and need not be too specific so as to be receptive to subjective impressions of the interviewee. Thus, the following questions are rather tentative, representing the exploratory initial stages of the research:

- What are the systems involved in the functioning of MAVs?
- What is MAV research?
- What is your perception of the popular understanding of this kind of research?
- How do you communicate with members of the press?
- What are the aesthetics of MAVs?
- What inspires you as a researcher?
- What are some of your experiences in the recent MAV competitions?

8. POTENTIAL BENEFITS AND ANTICIPATED RISK. (If risk of physical, psychological or economic harm may be involved, describe the steps taken to protect participant.)

-Opportunity to share experience of research with another person.

-No more than minimal risk.

9. DESCRIBE HOW PARTICIPANT(S) WILL BE RECRUITED, THE NUMBER AND AGE OF THE PARTICIPANTS, AND PROPOSED COMPENSATION (if any):

-Participants will be contacted by telephone to request interviews.

-5-8 subjects between the ages of 20 and 60.

-No compensation will be provided.

10. DESCRIBE THE INFORMED CONSENT PROCESS. INCLUDE A COPY OF THE INFORMED CONSENT DOCUMENT (if applicable).

An informed consent form will be distributed to each participant (see attached).

_____

Principal Investigator's Signature

_____

Supervisor's Signature

I approve this protocol for submission to the UFIRB:

_____

Dept. Chair/Center Director Date

APPENDIX C
RESEARCH QUESTIONS

Re: UFIRB #2005-U-1112 (Phenomenology of Micro Air Vehicle Research)

Research Questions

Because of the nature of qualitative research (and phenomenology in particular), the research questions will evolve over the course of the study. I am also still in the process of 'bracketing', or eliminating my own preconceptions. Thus, these questions still reflect researcher bias. Ideally, the questions proceed from a general stance, and are not specific so as to be receptive to subjective impressions of the interviewee. The following questions are tentative, representing the exploratory initial stages of the research:

- Define MAV research.
- What are the systems involved in the functioning of MAVs?
- How do the members of the various labs communicate?
- What are potential uses for MAVs?
- What are the aesthetics of MAVs?
- What inspires you?
- Please talk about your experiences in MAV competitions.
- How do non-experts perceive MAV research?
- How do you communicate MAV research to the press?
- What is the government's role in MAV research?
- Is there anything you would like to add?

[The above document represents the original research questions submitted for IRB approval in December 2005. As noted, the questions evolved over the course of the research. The second question about MAV systems dropped out completely, for example. The question about inspiration was initially too vague, and became two-pronged, probing for personal and laboratory inspiration. My advisor reminded me to place emphasis on lived experience, anecdotes and focus on personalizing the questions. She suggested discussing family and friends' reactions to MAV research. Otherwise, questions about the importance of more abstract concepts, such as interdisciplinary research or qualitative analysis, quickly emerged as these became apparent as important invariant horizons. Further questions about motivation, hobbies, and science fiction eventually were incorporated into the protocol as well.]

APPENDIX D
SAMPLE LETTER TO CO-RESEARCHERS

[Thank-you letters were e-mailed to co-researchers with a copy of their transcribed interviews and individual textural-structural descriptions for verification.]

6/2/06

To _____:

Thanks for meeting with me for not just one, but three extended interviews and sharing your MAV experience. I appreciate your willingness to share insights, and probe deeper into your own philosophies regarding research and the MAVs.

Please find attached a copy of the interview transcript, and my brief synopsis. The synopsis is divided into two parts, one where I summarize the interview, and the other where I try to decipher themes, or "structures," from the interview. In this second part, these structures are numbered. (These will later be compared to structures in the other participants' interviews to form a composite description of MAV research.)

Could you please review this when you have a chance? Has the interview fully captured your experience of MAV research? Perhaps I have some blind spots. Please do not worry about grammar or spelling or anything, as I want to preserve an accurate transcript of exactly what you said.

Please respond in an email once you have had the chance to do this, and note any suggestions that could make the description more accurate. If you feel inspired to include more anecdotes, please do not hesitate. Also, may I have your age? I forgot to ask.

If there are any major problems, please don't hesitate to contact me directly by phone, though I will be out of the country until 6/19/06. My number is given below. I've greatly appreciated your participation in this study. I very much enjoyed meeting with you. You have been an integral contact person during my research process. I hope my synopsis accurately reflects your experience of MAV research, and that as a result it might enhance your research experience.

Sincerely and respectfully,
Mario
(941) 284-6054
mars@ufl.edu

P.S.
All participants get a pseudonym to preserve anonymity. Yours is "Dr. Peterson."

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BIOGRAPHICAL SKETCH

Mario Rodriguez was born in Boston, Massachusetts in 1978. His family moved to Tampa, Florida in 1989. He graduated with a B.A. from New College of Florida (Sarasota) in 2001. In 2006 he received his M.A.M.C. from the University of Florida College of Journalism and Communications, and enrolled in a doctoral program at the Annenberg School for Communication at the University of Pennsylvania (Philadelphia). He lives in Philadelphia