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# Affordances In The Design Of Virtual Environments

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# AFFORDANCES IN THE DESIGN OF VIRTUAL ENVIRONMENTS

by

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## ABSTRACT

Human-computer interaction design principles largely focus on static representations and have yet to fully incorporate theories of perception appropriate for the dynamic multimodal interactions inherent to virtual environment (VE) interaction. Theories of direct perception, in particular affordance theory, may prove particularly relevant to enhancing VE interaction design. The present research constructs a conceptual model of how affordances are realized in the natural world and how lack of sensory stimuli may lead to realization failures in virtual environments. Implications of the model were empirically investigated by examining three affordances: passability, catchability, and flyability. The experimental design involved four factors for each of the three affordances and was implemented as a $2_{IV}^{4-1}$ fractional factorial design. The results demonstrated that providing affording cues led to behavior closely in-line with real-world behavior. More specifically, when given affording cues participants tended to rotate their virtual bodies when entering narrow passageways, accurately judge balls as catchable, and fly when conditions warranted it. The results support the conceptual model and demonstrate 1) that substituting designed cues via sensory stimuli in available sensory modalities for absent or impoverished modalities may enable the perception of affordances in VEs; 2) that sensory stimuli substitutions provide potential approaches for enabling the perception of affordances in a VE which in the real world are cross-modal; and 3) that affordances relating to specific action capabilities may be enabled by designed sensory stimuli. This research lays an empirical foundation for a science of VE design based on choosing and implementing design properties so as to evoke targeted user behavior.

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I dedicate this work to my wife, Sheryl Anderson Gross. This effort has cost her more than it has me.

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# CHAPTER 1: INTRODUCTION

The potential of virtual environment (VE) technology has captured the imagination of the scientific community as well as the public at large. VE technology is exciting, both because it offers a unique approach to effective human computer interaction (HCI) design, and because it may support computer assisted task performance in new or unprecedented ways (Pejtersen & Rasmussen, 1997). Engineering communities presume that VEs offer dramatic advances in the ability to design HCIs in entertainment, education, training, and other computer assisted applications (Stuart, 1996). For example, VEs may provide a new tool for gaining understanding from information (Pejtersen & Rasmussen, 1997). VEs also figure prominently in popular television series. Popular science fiction assumes the routine creation and use of synthetic three-dimensional worlds as believable as the real physical universe (Vince, 1995).

VE interface designs are unique because they aim to represent a virtual world, in which users may experience a strong sensation that they are present in, or part of, a computer generated world. Since humans are experienced with operating in the real world, VEs may offer a more natural interface than more conventional HCI (Norman, 1993; Shneiderman, 1998). For example, one common HCI challenge is designing effective interfaces *to* databases but within the virtual world, it is possible to place observers at any point *in* a database, allowing them to adopt any convenient perspective (Anders, 1999). Although the VE represents a world, it is not necessarily bound by the conventions of the real world (e.g., it need not conform to the laws of Physics). For example, humans can be endowed with the ability to "fly" over a virtual map, which could simplify learning geography and applying that knowledge in planning navigation routes. Thus, ideas that are difficult to convey via conventional means may be more readily "experienced" in a virtual world. One of the most useful benefits of VE technology may be this ability to use unique data representation schemes to gain understandings and insights (Norman, 1993; Sheridan, 1992).

The representation of a virtual world in a VE may provide several important benefits for task performance, including: expanding human memory, enabling group collaboration, and supporting transmission of ideas across time and space (Norman, 1993). Conventional HCI design proceeds from the assumption that the tasks to be done are stable and strongly structured. Such systems tend to well support work focused on producing a specific product, such as a document, or making a calculation. In contrast, VE designs may proceed from the expectation that the tasks to be performed in them will be dynamic and free flowing, because they aim at representing a world with the complex interactions typified by real experience (Anders, 1999). Therefore, VEs should better support more dynamic, or loosely structured, tasks such as exploration or military training (Pejtersen & Rasmussen, 1997).

Despite their potential, current VEs have proved less usable than expected or desired (Stuart, 1996). Lombard and Ditton (1997) note that there is limited research as to whether these new interface technologies are more effective or efficient than conventional HCI technologies. For example, Pausch, Shackelford, and Proffitt (1993) demonstrated that greater immersion in a VE can increase task efficiency, but assert that more research is needed to identify the characteristics of tasks for which the VE enhances performance. Anders (1999) notes that VEs have been shown to be effective in communicating dimensional or geometric information to users, but less effective in enabling VE users to determine their behavioral reactions within those spaces.

Since VEs are implemented as computer interface devices closely fit to humans, improving VE design has both ergonomics and human factors challenges. The challenge for ergonomics is the design of VE components such as data gloves and visual display helmets (Kalawsky, 1993). The challenge for human factors is the design of the virtual world representation. Although the ergonomics challenges are significant, since a virtual world representation is realized primarily in the mind of users, the human factors issues may be more challenging (Vicente, 1999). Stanney, Mourant, and Kennedy (1998) classify the potentially unresolved human factors issues for the design of VEs as: 1) human performance issues, 2) health and safety, and 3) social implications.

There are unique human performance issues in VEs, as compared to conventional HCI, because the human performs differently in immersive (e.g., helmet-mounted display-based) environments than in non-immersive environments. One specific example is human perception in VEs, as the National Research Council's recent survey on VE recognizes by calling for research "on how well the design accounts for human perceptual and cognitive features for human responses" (Durlach & Mavor, 1995, p. 65). In a specific example, Dixon, Wraga, Proffitt, and Williams (2000) have shown that, just as in the real world, observers use their perceived eye-height to judge the size of objects presented in an immersive virtual environment. This is not true in non-immersive (conventional) displays, but appears to be spontaneously evoked in immersive environments.

Perception is at the core of human performance issues because it is fundamental to cognitive processing (Wallach, 1976; Warren & Wertheim, 1990). Existing HCI design principles assume perception is essentially a response to a sensory stimulus, and focus primarily on visual stimuli to the neglect of other sensory modalities (Card, Moran, & Newell, 1983). However, perception is more than just stimulus and response, including for example attention, motivation, and stimulus integration (Rensink, O'Regan, & Clark, 1997). Stimulus integration is the process of combining sensory stimulation in different modalities into a consistent understanding of the world. Human perception is always multimodal; therefore HCIs which seek to provide an immersive experience may need to account for multimodal stimuli if their users are to correctly perceive the information presented to them (Popescu, Burdea, & Trefftz, 2002; Sharma, Pavlovic, & Huang, 1998; Shimojo & Shams, 2001). If a user cannot perceive what a VE enables, then the experience may be frustrating and non-productive, decreasing the usability of the virtual environment.

A core human performance issue therefore in VEs is designing the virtual world representation in such a way as to enable user's perception, i.e., to understand what can and should be done in the virtual environment. HCI design principles do not, however, appear to adequately address perception. This suggests that a productive area of research is the extension and application of psychological theories addressing perception to the design of VEs (Barnard & May, 1999; Pratt, Zyda, & Kelleher, 1995). The question for VE designers is inverted, however, from questions addressed by traditional psychological theories. Instead of understanding how humans perceive what naturally occurs in the real world, VE designers need to understand how their designs support and exploit natural perception within the virtual world they represent. More specifically, the issue for VE design is how the user perceives the objects, properties, and behaviors selected by the VE designer for inclusion in the virtual world. This is a direct result of the fact that the only way for developers to communicate with users is through the artifacts of their design evidenced in the interface (Anders, 1999).

One compelling way of thinking about human perception is the theory of direct perception, which says that humans can (and do) directly perceive the possible actions in an environment or conversely what the environment affords to the human (Gordon, 1989). The issue is whether or not VEs can be designed to provide the same level of direct perception.

The theory of direct perception revolves around two concepts: affordances and invariants. Affordances are the inherent uses that an object in the world furnishes to their user, for good or ill. Invariants are higher-order properties or patterns of stimulation, which remain constant during changes associated with the observer, the environment or both. Affordances are therefore a form of communication between objects and their users, and invariants a model of how they are used (Gordon, 1989). Affordance theory explains the interaction of an organism with its environment, under the premise that perception is an important cognitive process (Gibson, 1979).

The present research investigates the resulting implication that VE interface designs which are sensitive to the match between their actual affordances and their intended functions should be more usable than affordance insensitive designs. The present research first constructs a conceptual model of how affordances are realized in reality and how sensory stimuli missing in a VE prevent the realization of affordances in virtual environments. Second, the research aims to demonstrate that VE designs can enable the realization of affordances by overloading of absent sensory stimuli modes onto sensory modes extent in the interface. Finally, the research aims to demonstrate that VE designs that enable affordances are more usable, in terms of ease and efficiency of user movement, than VE designs that do not.

# CHAPTER 2: BACKGROUND

## Perception and Multimodal Sensory Stimulation

Humans, like all animals, experience their natural environment through continual multimodal sensory stimulation, and this multimodal stimulation is fundamental to correct perception. In a famous experiment, Lee and Reddish (1981) while observing the behavior of gannets (a bird that feeds by diving on fish in water), determined that the bird's decision on when to fold its wings for entry into the water was a function of the stimulation available to the bird in the visual and kinesthetic sensory modalities. In a fundamental finding for human perception, Gibson and Mowrer (1938) showed that the perception of uprightness is complex, dependent on integration of visual and kinesthetic (e.g., the effect of gravity on posture) information. Gravitational factors were shown to be preeminent to visual factors in the determination of the perceived vertical, although distorting visual information led to a distorted perception of the vertical. Similarly, Cutting, Wang, Fluckiger, and Baumberger (1999) provide a summary of literature arguing that pedestrians integrate visual stimuli with kinesthetic and vestibular information in order to make heading judgments. Kolev, Mergner, Kimmig, and Becker (1996) showed that perception of object motion in space in the absence of a visual background depends strongly on vestibular and visuo-oculomotor cues.

The fact that humans experience the natural world through continual multimodal sensory stimulation has significant implications for the present research. If VEs seek to provide immersive experiences, e.g., experiences where the user feels a strong sense of being part of the virtual world, then it is likely that such HCIs will have to address the user's natural expectation of multimodal sensory stimulation. Sharma et al. (1998) suggest biological, mathematical, and practical reasons for using multimodal human computer interfaces. Biologically, sensory signals from all sources converge to the same target area in the superior colliculus, which also receives signals from the cerebral cortex, which in turn regulates behavior. The majority (~75%) of neurons leaving the superior colliculus carry multisensory information. This implies that not only do humans experience the world through continual multimodal sensory stimulation; their brains are "wired" to accept such stimulation, which increases the likelihood that single or limited mode stimulation will not always lead to correct perception. The mathematical motivation for using multimodal HCIs is that statistical data analysis suggests that increased accuracy results from combining multiple sensory sources. Just as multiple samples can improve the accuracy of an estimated population parameter, multiple observations in different modalities of the same source can be combined to increase the accuracy of the understanding of the source. Finally, the practical reasons they cite include increased naturalness, robustness, and accuracy, all of which VE systems aspire to achieve.

Ordinary understanding names five sensory modalities (sight, hearing, touch, taste, and smell) by which humans perceive their environment. However, this understates the complexity of the human sensory system. Table 1 shows specific human sensory modalities by category, and the kinds of information they transduce (Forgus & Melamed, 1976). Transduction is the process by which sensory systems translate physical information available in an environment into information messages on which the nervous systems acts. All sensory systems transduce four kinds of information: 1) sensory modality and sub-modality, 2) stimulus intensity, 3) stimulus duration, and 4) stimulus location (Forgus & Melamed, 1976). Exterocepters are sense organs that are adapted for transducing energy from external stimuli (i.e., those outside of the body, such as light and sound). Proprioceptors are sense organs that respond to direct contact with external stimuli (e.g., taste, smell, pressure). Interceptors are sense organs that respond to internal stimuli within the body itself (e.g., body motion, balance, thirst).

Table 1: Human senses and information transduced (Forgus & Melamed, 1976).

| Class | Sense | Energy Transduced |
|---|---|---|
| Exterocepters (distance) | Vision | Light |
| | Audition | Sound |
| Propriocepters (near) | Cutaneous (skin) | Pressure, temperature |
| | Gustation (taste) | Chemical (liquids) |
| | Olfaction (smell) | Chemical (gases) |
| Interceptors (deep/internal) | Kinesthetic (dynamic) | Body motion |
| | Vestibular (static) | Body balance, rotation, acceleration |
| | Organic | Organ function, such as thirst, hunger |

The variety of sensory modalities and energies transduced by the human senses has at least two implications for VE interface designs. First, such designs may need to account for all modalities if they are to create a truly immersive experience. There are three alternatives for accounting for the modalities: 1) correlate sensory stimuli to the experience represented in the virtual world, 2) determine a particular modality is irrelevant to the experience, or 3) substitute information in another modality for missing modalities. Second, VE interface designs face a difficult challenge if they seek to present sufficient stimuli to enable a truly comprehensive correlation of all possible sensory modalities, because of the complexity of the modes and stimuli.

It is possible to construct a model of a human interacting with its environment via these various sensory modalities. Figure 1 illustrates such a model, showing multimodal sensory stimulation as integral to correct perception in humans. Within this model there are two classes of sensory modalities: external and internal. Changes in the internal organs produce internal stimuli, whereas changes in the external environment produce external stimuli. Occasionally, perception begins with changes in internal stimuli, e.g., changes in the organic sense might lead to the perception of hunger. Typically however, perception begins with external stimuli arising from objects in the environment, which transmit or reflect energy to an organism. These external stimuli arise as energy from objects in the environment forms a distal stimulus, which is energy reflected or transmitted as measured at the object. When the stimulus energy reaches a sensory receptor (e.g., the eye), it becomes a proximal stimulus. There is an energy loss between the distal and proximal stimuli, which is due to environmental effects such as water vapor and air pressure. As the peripheral components (i.e., sensory receptors) are stimulated, they emit mediated stimuli which are nerve impulses moving to the central nervous system from the peripheral nervous system (a process called affection). The perception process is complete when the organism forms a "precept" (that which is perceived), and which in humans is generally multimodal (Reber, 1995). This precept forms a basis for other cognitive activities, which lead to decisions to select and exercise environmental effectors, such as the arm or leg.

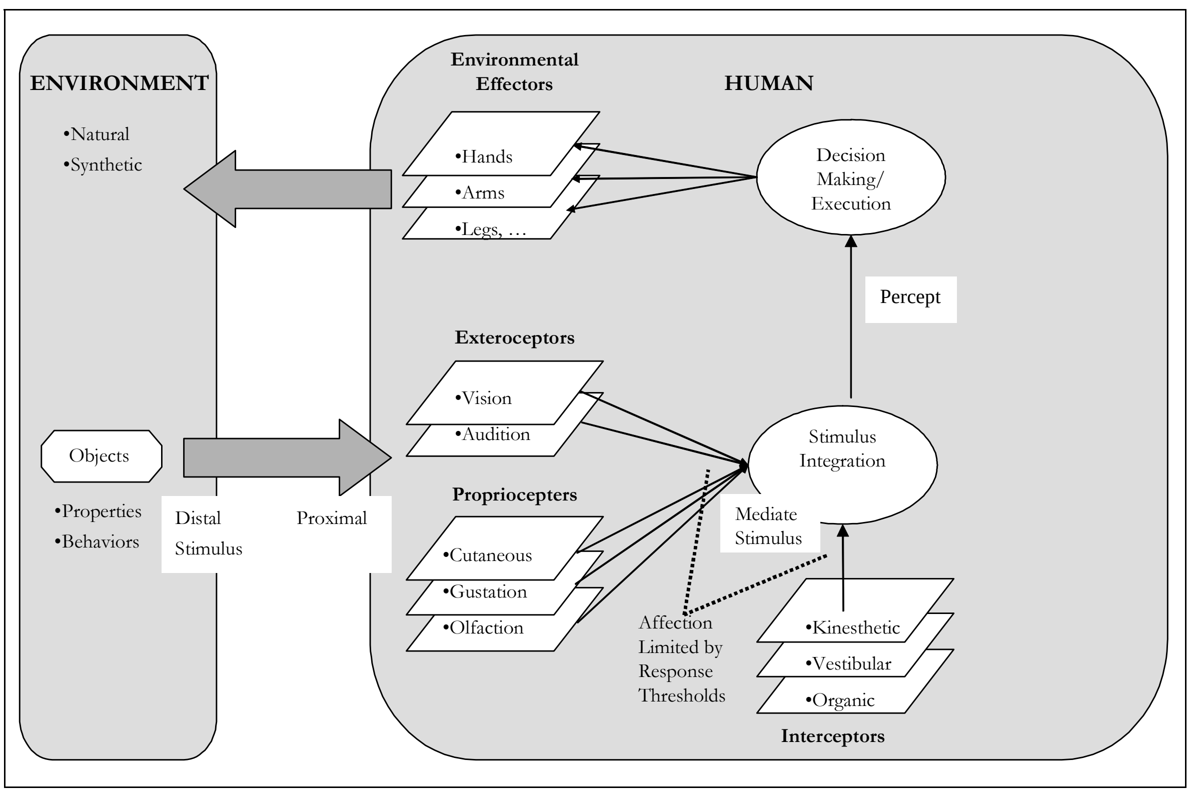


Figure 1: Multimodal sensory stimulation integral to correct perception.

The use of precepts results in decisions by the human that affect the environment, which in turn leads to new environmental stimuli. It is through such decisions and resulting actions that the human has influence on the environment, either changing the environment itself or one's position in it. The human's observation of the stimuli-decision-action cycle becomes a feedback cycle that also affects perception (Norman, 1988). As such, the specific environmental effectors available and the individual's experience with them, have influence on the precepts formed. For example, the human perceives a surface is suitable for walking both because of the stimuli the surface presents to the senses, and because the human has legs capable of walking. The human does not perceive whether a space is suitable for flying, until equipped with a capability for flying. Such additional capabilities may be real (e.g., the human is flying a plane) or potential (e.g., the human is considering flying a plane) or fanciful (e.g., the human is given wings). The human's knowledge of and experience with environmental effectors leads to an understanding of the available action capabilities using those effectors, such as walk, crawl, run, etc. In a like fashion, additional internal state information such as current goals, motivations, and knowledge of stature (e.g., size, reach …) influence perception (Marik, 1987; Norman, 1988; Rensink et al., 1997). For a percept to be formed, such internal state information and environmental multimodal sensory stimuli must have a certain intensity and duration to be perceived.

Environmental and internal state stimuli exist continually, however; the human sensory system is primarily designed to capture significant *changes* in such stimuli. As aforementioned, all sensory systems transduce information on stimulus intensity and duration. Some stimuli are of insufficient intensity or duration to activate a response in a particular sensory modality, and therefore fall below the response threshold for the sensory receptor involved. The minimum thresholds vary for each sensory modality, and indeed for different sensory receptors within a modality, e.g., rod and cone cells in vision. Stimuli failing to rise above this minimum threshold do not lead to new percepts. Further, different individuals respond with different sensitivity to stimuli. It is, however, possible to construct a response function curve that approximates the response threshold for a population (Grandjean, 1988). There are many techniques for determining a response function. Figure 2 illustrates a typical psychophysical response function (Proctor & Proctor, 1997). The response threshold is the stimuli intensity that is detected 50% of the time (an arbitrary threshold). The S-shape of this curve results from the typically normal distribution of the population being sampled.

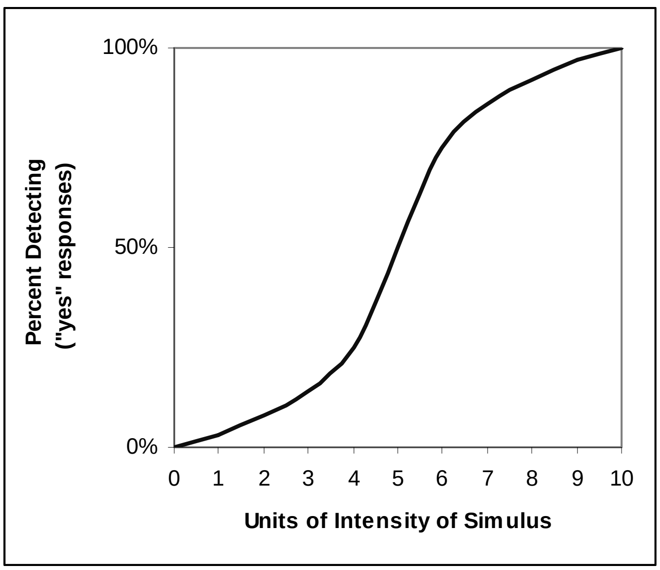


Figure 2: Typical S-shaped psychophysical function.

VE designers can exploit these minimum response thresholds. Watson, Walker, Hodges and Reddy (1997), for example, applied knowledge about the capabilities of the human visual system to the problem of reducing demands on visual scene rendering. Seeking to reduce computational demands associated with rendering a visual scene for a VE, they found that they could exploit the non-uniformity of human vision by managing the level of detail of visual information at the periphery. By degrading the quality of the rendered scene only at the periphery, they succeeded in lowering computational requirements while not affecting task performance. That there are minimal response thresholds for each sensory modality has significant implications for VE system design. If a designer wants users to perceive a stimulus, it must exceed the minimal threshold, and if the designer is seeking to avoid users perceiving a stimulus (e.g., lag), it must fall below the threshold.

Substantial research has been conducted into the response thresholds specifically of exterocepters (visual and auditory senses) and toward exploiting this information in HCI (see Cain & Algom, 1997; Forgus & Melamed, 1976; Grandjean, 1988; Proctor & Proctor, 1997; Regan, 2000; Wallach, 1976). The visual and auditory senses are accessible in the sense that video and multi-channel sound systems provide a reliable means of providing stimuli to the visual and auditory senses. VE designs can present visual and audio stimuli, which completely replace stimuli from the natural environment, although such stimuli may not have a sufficient degree of fidelity to make the observer believe it is real. As a result, VE designers can develop and correlate such synthetic visual and audio stimuli with the virtual experience desired.

In contrast with exterocepters, the response thresholds of propriocepters are only generally known (e.g., sensory attributes of the skin are still difficult to quantify and exploit) and those of interceptors are even less well known (Proctor & Proctor, 1997). Further, there exists no reliable and economical way of providing propriocepters and interceptors with artificial stimuli (Barfield & Furness, 1995; Vince, 1995; Stuart, 1996). As such, propriocepters and interceptors are inaccessible as compared with exterocepters. Further, while propriocepters and interceptors may play an important role in perception particularly in awareness of self, VE designers have little understanding and inadequate means for creating artificial stimulation for these senses, or for correlating such with the desired virtual experience. As a result, if VE users experience propriocepters and interceptors stimuli they will likely be from their natural environment (e.g., weight of the Head Mounted Display [HMD], or pressure of the chair they sit in during immersion) and may be in conflict with the synthetic world within which they are immersed. In contrast, exterocepters can be stimulated with information correlated to the desired virtual experience.

This inability to provide stimuli to propriocepters and interceptors is a problem because some of the percepts that VE designers desire to enable may depend on the integration of multimodal sensory stimulation including propriocepters and interceptors. Thus, substitution schemes for the inaccessible stimulation of propriocepters and interceptors may need to be pursued to enable correct perception. More specifically, designers could determine if it is possible to use available exterocepters, such as visual and auditory stimuli, to provide perceptual cues for requisite but absent propriocepter and interceptor stimuli. Such schemes would not replace the continual natural stimulation of propriocepters and interceptors. Nor would it change the affection of nerve signals resulting from this natural stimulation, since there are at present no direct neural inputs that can substitute for the propriocepters/ interceptors to central nervous system connection. The objective of such substitution schemes would be to enable correct perception by providing stimulation via exterocepters, outweighing the ongoing natural stimulation of propriocepters and interceptors (e.g., from the HMD, chair, etc.), or substitute artificial stimulation for propriocepters and interceptors correlated to the virtual environment. When natural stimulation falls below the response threshold of a sensory modality (such as occurs in the kinesthetic sense when not moving a limb), substitute stimulation would simply have to exceed the response threshold. When natural stimulation exceeds the response threshold, substitute stimulation would have to exceed the natural stimulation by a sufficient amount related to the response threshold to force response to the substitute rather than the natural.

Such schemes may succeed for two reasons. First, propriocepters and interceptors stimuli are relatively weak during typical human-VE interaction because of lack of user movement, as well as lack of other sensory modality stimulation (e.g., taste, smell). Unless there is a motion base involved, users generally do not have any intrinsic need to shift body posture to any great degree during VE exposure, except for invoking arm and hand motions, which relate to the virtual experience. While propriocepters and interceptors are continually stimulated, they detect best changing stimuli and eventually cease detection if continually exposed to the same stimuli (Forgus & Melamed, 1976; Proctor & Proctor, 1997). For example, a human who is not moving "forgets" the position of the body's limbs, although a very slight movement is all that is required to perceive the body's position. This implies that exterocepter sensory substitution schemes are more likely to succeed if stimulation of propriocepters and interceptors is minimized, perhaps by immobilizing the user.

Second, a substitution scheme may succeed because perception depends on integration of various sensory stimuli. Reber (1995) for example, defines perception as collectively, 1) the processes that give coherence and unity to sensory input; 2) awareness of a process; and 3) synthesis and fusion of elements of sensation. While the formation of mediate stimuli, that is, the conversion of the stimuli presented to the senses into nerve signals for transmission to the central nervous system, is understood to some extent, much less is understood about how these stimuli are integrated into a precept. The mechanics of sensory integration are not well understood, however, conclusions about the relative importance of various sensory modalities in the sensory integration process can be drawn from observations about the structure of the brain (Kadunce, Vaughan, Wallace, & Stein, 2001; Popescu et al., 2002; Sharma et al., 1998). Specifically, the brain devotes relatively large portions of its processing capacity to processing visual sensory stimulation, so it may be argued that visual information has relatively more weight in the sensory integration process (Proctor & Proctor, 1997). This leads to the phenomena of visual dominance, which refers to the preeminent influence that visual stimuli have on perceptions. Stein and Meredith (1993) note that unless stimuli in a competing sensory modality are especially intense, visual stimuli provide the basic influence as to the interpretation of sensory stimulation One example of this is the ventriloquism effect in which the visual stimuli of a dummy's mouth leads to the perception that the dummy is actually speaking (Storms, 2002). This has important implications for a sensory substitution scheme, because it suggests that such a scheme may exploit the relatively greater weight of the visual sense in substituting for other senses.

The literature includes findings that support this design approach. Ijsselsteijn, Freeman, de Ridder, Avons, and Pearson (2000) measured posture responses to moving video, with various quality of display gear, and found that indeed posture changes were more noticeable when more immersive, higher resolution displays were used. Regenbrecht, Schubert, and Friedmann (1998) showed that visual displays such as those used in VEs can induce emotions, specifically the fear of heights. This is a strong indication of the ability of visual displays to evoke perceptions even when they are not correlated with other sensory stimuli normally associated with a given percept. For example, a moving picture can evoke the sensation of motion through visual stimuli, even though interceptors do not indicate motion.

The appropriate visual or auditory exterocepter stimuli to substitute for propriocepters and interceptors that are not correlated to the desired virtual experience would naturally depend on the perception to be enabled. It is therefore essential to develop an understanding of how the role of the senses in perception may be transformed while immersed in a VE and how this will affect integration of perceived stimuli into a percept via the (likely different, possibly diminished) action capabilities that can be realized in a virtual environment. One model that ties the attributes of objects that stimulate sensory modalities to the actions that can be taken with those objects is the theory of affordances. As aforementioned, affordance theory describes how humans directly perceive objects in their environment.

## Affordances

The success of a sensory substitution scheme depends on an understanding of how the factors discussed: multimodal stimuli, available effectors, experience, attention, consistency, motivation, organization, attitude, and learning; are integrated into a percept. If this integration process is well understood, then designers can exploit that understanding in their design of sensory substitution schemes. The integration process required to form a percept is not at this time well understood (Rensink et al., 1997). Figure 1 illustrates this lack of understanding by representing the process of integration to form a percept as a "black box". Various models of this process can and have been constructed, which explain this integration to a greater or lesser extent (Wertheim, 1994). One powerful model of this process is presented by the theory of direct perception, in particular its concept of affordances. Affordances may be particularly relevant to the problem of designing a sensory substitution scheme because affordances draw heavily from an integrated perspective of animals acting in and directly perceiving their environment.

### Definition

Direct perception, or ecological psychology, was first advanced by J.J. Gibson (Gibson, 1979). J.J. Gibson's theory of perception derives from his assertion that most of our knowledge of the world around us is not simply based on our experience, but on our expectations. Gibson's theory revolves around two concepts: affordances and invariants (Gordon, 1989). Affordances are the inherent uses that an object in the environment furnishes to their user, for good or ill. An object is said to afford a function to potential users. An object's complete set of affordances defines its possible functions. Affordances are therefore a form of communication between objects and their users. Humans tend to use objects in ways suggested by the most conspicuously perceived affordances, not in ways that are difficult to discover. Invariants are higher-order properties or patterns of stimulation, which remain constant during changes associated with an observer, the environment or both (Gordon, 1989). Affordances are neither objective properties, nor are they purely perceptual (Kuhn, 1996). They capture how human beings understand what they can do with their environment. Affordances offer clues to the environment's operation. Researchers in direct perception have somewhat varying notions of just what an affordance is, although a general consensus emerges in Table 2 by comparing definitions found in various works, and arranging them in chronological order.

Table 2: Various definitions of affordances.

| Researcher | Definition |
|---|---|
| Gibson (1979) | The inherent uses that entities furnish to their user, for good or ill |
| Warren (1984) | Functional utilities of an object for an animal with certain action capabilities; they exist whether or not they are perceived |
| Bingham and Muchisky (1992) | Dispositional or relational properties |
| Reber (1995) | The "invitational" quality of a percept for an event; intrinsic properties of items and events |
| Kuhn (1996) | Captures how a human understands what can be done in an environment |
| Oudejans, Michaels, Bakker, and Dolne (1996) | Active pickup of meaningful information that specifies the behavioral possibilities of an environment |
| St. Amant (1999) | Relationships or properties of relationships or<br>Actions (actual, potential actions) or<br>Perceived properties or<br>Mental constructs |
| Lintern (2000) | Functional properties |

A simple example will serve to illustrate. It is clearly seen that a chair affords *sitting* to humans. What is less clear is how a chair accomplishes this affordance while at the same time affording many other possible functions, for example: standing, climbing, blocking, and bashing. How is this possible? The goal "to sit" is invariantly associated with certain properties. What properties are sought in a place to sit (i.e., a seat)? Humans want seats that are flat, level, knee height, and so forth. There is an acceptability range for each property: The seat need not be perfectly flat, or exactly at knee height for example. The invariants associated with sitting explain how humans are able to instantly adapt to an incredible number of seats, including chairs never sat on and chair designs never before seen. In addition, other invariants are associated with other possible affordances of the chair.

Table 3 shows a non-exhaustive list of affordances and the invariant characteristics that support them. The list of satisfying objects shown for each affordance illustrates that affordances and their invariants are not perfect selectors – a wide variety of objects, not all good, may support realization of a specific affordance. Affordances are neither good nor bad, nor healthy or unhealthy – they are simply potential uses of an object.

Table 3: Examples of simple affordances and their invariants.

| **Affordance** | **Invariant Characteristics** | **Satisfying Objects** |
|---|---|---|
| To Walk | Flatness, width, steepness, ... | Path, road, fallen tree, ... |
| To Sit | Flatness, steepness, height, ... | Chair, bench, stool, table, ... |
| To Lie Down | Flatness, width, softness, ... | Bed, cot, sleeping bag, ... |
| To Drink | Taste, smell, viscosity, ... | Water, milk, poison, ... |
| To Eat | Taste, smell, color, ... | Steak, fruit, okra, plastic, … |

Since VEs create an artificial environment, and affordances describe how humans operate and adapt to the real environment, it seems natural to consider basing VE designs on affordances. This approach ought to create interfaces that are more natural, i.e., behave in more understandable and reliable ways, than designs that are not sensitive to their affordances. Natural designs ought to be easier to learn to operate, adapt better to user tasks, and frustrate users less because users would be able to apply the same skills that they have acquired in the real world (Norman, 1988). Many researchers have suggested such an approach (Eberts, 1994; Lintern, 2000; Norman, 1988; Pejtersen & Rasmussen, 1997; St. Amant, 1999). Kensing and Munk-Madsen (1993), in discounting existing HCI methodologies, state that the most important task in HCI design is to focus on models that enhance communication between users and developers. This directly evokes Gibson's claim that affordances can serve as a source of communication between a world and its inhabitants. The desirability of this approach is re-enforced when it is realized that the only way for developers to communicate with users is through the artifacts of their design evidenced in the interface (Anders, 1999).

The question arises as to which affordances are relevant to VE design, and therefore should be represented. For example, eating and drinking are not generally considered tasks suitable for performing in virtual environments. One might begin by considering affordances in the natural environment, however, there presently does not exist any complete, exhaustive characterizations of affordances in the natural environment. While the concept of an affordance is reasonably accessible, the construction of a formal structure of affordances and their inter-relationship is less obvious. In their study of the affordance of graspability, for example Bingham and Muchisky (1992) discuss the problems with trying to define a comprehensive structure of affordances. There is both tremendous functional variability and similarity between closely related terms such as "grasp", "lean", "support", or "trap". It is difficult to cleanly separate these concepts, much less objectively determine whether a particular affordance is being exploited in a particular task. Shaw, Flascher, and Kadar (1995) classify affordances by the invariants that describe them, specifically geometric (sized to body stature or characteristics) or kinetic (sized to action capabilities). While this classification provides insights into the nature of affordances and their invariants, it does not provide helpful insights into the problem of choosing which affordance(s) to represent in a virtual environment. A different approach would be to consider the kinds of tasks performed in VEs, and the affordances that would relate to them. The VE Performance Assessment Battery (VEPAB) provides such a set of tasks. The VEPAB is a set of tasks designed to support research on training applications of VEs (Lampton, Knerr, Goldberg, Bliss, Moshell, & Blau, 1994). Table 4 itemizes the affordances that relate to VEPAB tasks.

Table 4: Tasks in the virtual environment performance assessment battery.

| **VEPAB Task Category** | **Corresponding Affordances** |
|---|---|
| Vision | To Recognize |
| Locomotion | To Walk<br>To Fly |
| Manipulation | To Grasp |
| Tracking | To Align |
| Reaction Time | To Choose |

The use of affordances in VE design is certainly not a straightforward application. First, direct perception has a theoretical shortcoming for perception in synthetic environments such as a virtual environment. Direct perception specifically addresses perception in a natural environment (which is why the theory is sometimes called Ecological Perception), and denies the ecological validity of synthetic environments (Gibson, 1979). Second, direct perception offers no method for applying the theory to interactive system design. Okamoto (1997) states that affordance theory does not seem to be practical, because the theory is so philosophical that designers have no idea how to apply its theoretical statements to the design of human interfaces. Eberts (1994) suggests that deciding on which affordance to associate in a design is an extremely difficult problem. The lack of a practical theory of affordances means there is presently no practical technique for discovering affordances (Fitzgerald & Goldstein, 1997). Bingham and Muchisky (1997) argue that while some researchers have suggested that affordances are revealed in the intrinsic properties of an item, others have attempted to find an affordance in the dynamic behavior of the item. Neither approach has proven generally effective.

As argued in the previous discussion, perception in any environment depends on sensory stimulation in the sensory modalities available to the human. An understanding of the role of sensory stimulation in the realization of affordances could potentially provide an approach to affordance-based design. A number of researchers (Gibson, 1979; Schöner, 1994; Sanocki & Epstein, 1997; Wertheim, 1994; Cutting, Vishton, Fluckiger, & Baumberger, 1997; and Cutting et al., 1999) have pursued the realization of affordances in the natural environment as primarily, if not exclusively, a function of the visual modality. Figure 3 summarizes a number of these studies. For example, Cutting et al. (1999) found that humans make heading judgments independent of object-based motion; instead they depend on visual information such as the displacement direction of the nearest object, inward displacement toward the fovea, and outward deceleration. These studies are valuable in that they demonstrate Gibson's fundamental view of affordances, that the visual field is rich with information about the environment enabling correct perception and action in it. A number of researchers (Gibson & Mowrer, 1938; Runeson & Frykholm, 1981; Lee, Reddish, Lough, & Clayton, 1983; Cohn, Dizio, & Lackner, 2000; Kolev et al., 1996; Warren, 1984; Warren & Whang 1987; Marik, 1987; Bingham & Muchisky, 1992; Oudejans et al., 1996; Turvey, Shocklet, & Carello,

1999) have provided research that supports the role of non-visual sensory information in the realization of affordances, at least in natural environments. This body of research demonstrates that the perception of affordances depends on multiple sensory modalities, such as the vestibular and kinesthetic sensory modes. For example, studies such as Warren (1984), Warren and Whang (1987), and Marik (1987) all showed that an understanding of body stature, i.e., self-perception of body stature in the environment was critical to geometric affordances. Lee et al. (1983), Oudejans et al. (1996), and Turvey et al. (1999) showed that kinematic affordances depend on self-perception of action capabilities, i.e., what the individual can do in the environment.

A useful body of research focusing on the exploitation of affordances in the design of synthetic environments exists. Studies such as St. Amant (1999), Gattis and Holyoak (1996), Rensink et al. (1997), Pejtersen and Rasmussen (1997), Gossweiler, Profitt, Bhalla, and Paush (1997), Regenbrecht et al. (1998), Kourtzi and Shiffrar (1997), and Cutting (1997) are chiefly concerned with the role of visual information as it contributes to affordance realization in virtual environments. St. Amant (1999) is the most complete work in this group, presenting an affordance-based approach for designing artificial intelligence planning tools. This work has modeled a planner's user interface as a set of interface operators and preconditions that must exist for a specific action to cause its related affordance to exist. A second group of studies presents evidence that affordance realization in VEs is multimodal (just as it is in natural environments), as typified by Ivanenko, Viaud-Delmon, Sigler, Israel, and Berthoz (1998), Dixon et al. (2000), Stappers (1999), Popescu et al. (2002), Van Der Steen (1996), Kalawsky (2000), Storms, (2002), and Ijsselsteijn et al. (2000). In general, these studies demonstrate that most affordances of interest depend on sensory stimulation other than simply visual, such as kinesthetic and vestibular sensory information. Stappers (1999) is of particular interest, as it provides evidence that affordances that depend on multimodal sensory stimuli are not extant when required modalities are impoverished. For example, Stappers found that VE users did not rotate their bodies to pass through doorways, as Warren and Whang (1987) found with subjects in the natural environment. Yet, none of these studies explored how to enable the realization of affordances when the sensory modalities required to realize an affordance are impoverished. As suggested by the prior discussion, the problem of impoverished sensory modalities in VEs might be addressed by a sensory substitution scheme. There is currently little, if any, research investigating such sensory substitution schemes in HCI (see Figure 3). Indeed, there is comparatively little research on sensory substitution schemes in natural environments. The research regarding sensory substitution in natural environments arises chiefly from two sources: distracting patients in pain and assisting persons with sensory system defects. In the case of pain distraction, the substitution is to provide sensory stimuli that lead to a perception other than pain. For example, Yamasaki, Kakigi, Watanabe, and Daisuke (1999) and Rode, Salkovskis, and Jack (2001) showed that visual and audio distractions can block pain in some circumstances. In the case of persons with sensory system defects, the substitution is to provide stimuli in an operating modality to replace the defect. Shimojo and Shams (2001) point out that sensory deprivation in early life generally leads to plasticity, in which the cortical area normally devoted to that modality is used by other modalities. Further, Curran, Schacter, and Galluccio, (1999) showed that cross modal priming can assist patients with an impaired ability to convert visual representations of words to speech. These studies suggest that humans are adaptable to sensory substitutions and further, that they can learn to leverage the displaced information to realize affordances. Thus, such schemes could prove useful in VE design to displace missing stimuli that are naturally associated with a given affordance. In order to determine how to develop such schemes, it is first essential to identify how affordances are realized during human perception and potential factors that lead to realization failures.

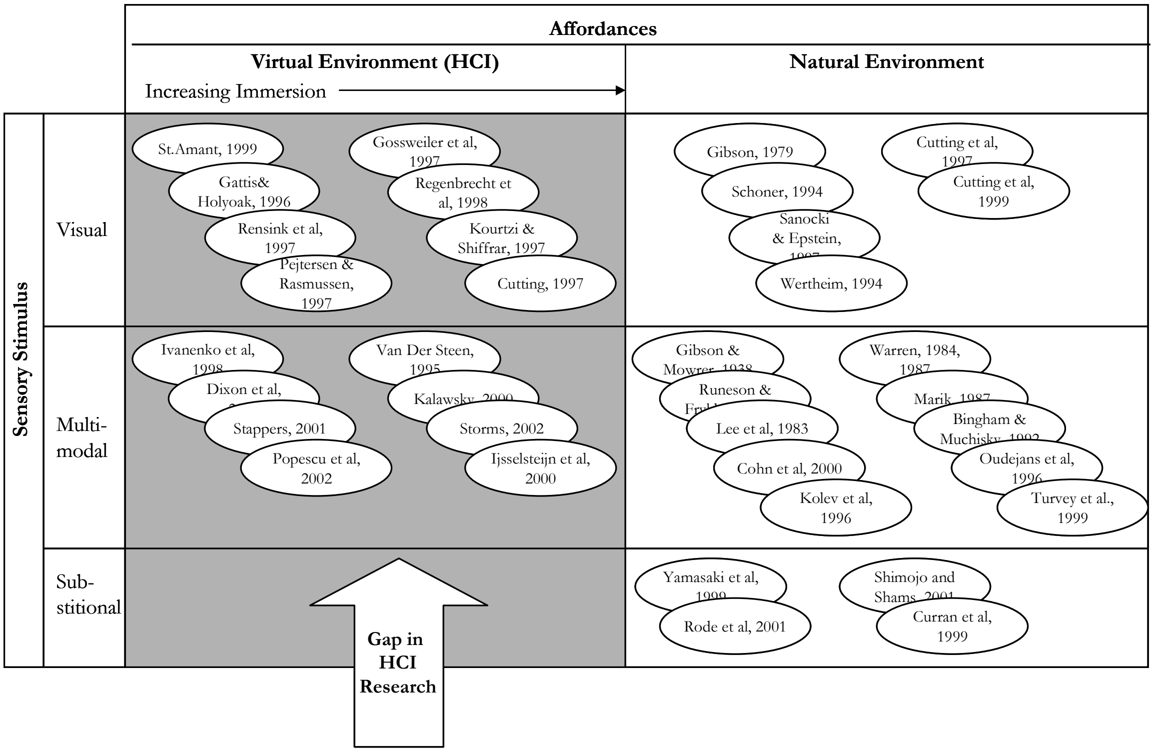


Figure 3: A gap in the present HCI research.

## Realization of Affordances

Affordances are a model of how animals form percepts, which reflects a natural integration of the variety of sensory stimuli and other factors known to affect perception. A consideration of the factors affecting the realization of an object's affordances provides insights into how they can be designed into objects in a virtual world. Gibson, Riccio, Schmuckler, Stoffregen, Rosenberg, and Taormina (1987) claim that two types of information are required for realizing an affordance: 1) information specifying properties of the thing perceived, and 2) information about the relevant capacity and structural constraints of the perceiver. Along these lines, Allard (1999) has suggested criteria to be met sequentially to validate the existence of an affordance:

1) Subjects must show consistent perceptual judgments of the critical or optimal point of the percept (i.e., a repeatable threshold in terms of sensory stimuli),

2) Subjects must show consistent actions (i.e., a phase transition in behavior made at the critical point), and

3) Perceptual and action points should be the same for each subject, when scaled appropriately to the subject's size.

If the realization of affordances depends on perceptual judgments, then their realization will depend on sensory thresholds. Since Gibson (1979) claims that affordances are perceived in the natural world, they must be sufficient to activate one or more of the sensory systems, i.e., they must arise from sensory stimulation that exceeds the minimum response threshold of the sensory modalities involved. However, Gibson distinguishes between the stimulation of receptors in the sensory system and activation of that system. He provides a useful example explaining his emphasis on the sensory system, versus simply the receptors. In homogeneous darkness, the vision sensory system fails for lack of light, but in homogeneous light (e.g., fog) vision fails for lack of information. Both situations are real failures of the vision sensory system to perceive (Gibson, 1979). Failure for lack of light is an example of failing to exceed minimum response thresholds; failure for lack of information arises even though the minimum thresholds have been exceeded by the stimulation. The implication for the current study is that the sensory stimuli provided in a VE must not only exceed minimum response thresholds, but also be sufficiently organized to be understood.

What about affordances and multimodal stimuli? Warren and Whang (1987) argue that perceiving an affordance implies perceiving the relationship between the environment and the observer's own action system, in particular correspondence between the vision and kinesthetic sensory systems. For example, in the case of an aperture in a wall affording passage, such as a doorway, they empirically determined that the ratio of aperture width to shoulder width should be 1:1.3 or greater to realize an affordance of easy passage. Since this study investigated passage as a visually guided action, the aperture was certainly visible. But one's shoulders are not completely visible – at best they fall in the peripheral field of vision. Indeed, the perception of the passability affordance depends on at least two sensory modalities, vision (for aperture width) and kinesthetic (for body dimensions), as well as additional factors such as attention and motivation, and the human's action capability of walking. This raises a challenge for VE design, that if an affordance that depends on multiple sensory modalities is to be realized, then the VE design must present sufficient information in the required modalities, or substitute sufficient information in other modalities. The following discussion looks more closely at how such realization occurs.

A synthesis of the affordance literature yields six principles about how the various factors involved in perception are integrated into a percept via the realization of an affordance. Each of these assertions about the realization of affordances provides implications for VE designers seeking to enable correct perception.

***Affordances depend on objects in the environment.*** Self-evidently, different object properties/behaviors result in different affordances. This is the very essence of what it means for objects to be different. A chair is different from a wall because it provides different affordances. The organism can perceive the same affordance from multiple objects, but some objects provide a stronger (better fit) affordance than others (St. Amant, 1999). For example, in a room of varying height chairs, the one closest to the observer's knee height will best afford sitting. Shorter chairs may well be treated as stools affording climbability. The specific properties of objects in the environment that evoke particular circumstances, such chair height or passage width, may be thought as evoking circumstances. This can be thought of as a "goodness of fit" function for affordances. Designers should thus try to endow objects with properties that are relevant to an individual's purpose within a VE system and thus afford desired skills and appropriate behaviors. In terms of Figure 1, this means that the selection of specific objects and properties in a VE design determines the affordances that may be realized by VE users.

***Affordances depend on the organism's action capabilities***. Obviously, different action capabilities result in different affordances. For example, the surfaces that afford walking to quad-pedal creatures (e.g., a horse) are different than those that afford walking to bipedal creatures (e.g., humans). Animals with relatively rare action capabilities such as flying are afforded different things by their environment than animals that do not possess this capability. Specific to humans, Oudejans et al. (1996) showed that the affordance of catchability related to kinematic action capabilities such as speed and acceleration. Designers should provide affordances that engender appropriate action to attain relevant goal-oriented behavior. In terms of Figure 1, this means that the feedback loop, which begins with an actor making and executing decisions, which causes change in an environment, and which are then observed by the actor, affects the realization of affordances.

***Affordances depend on physical characteristics of the observer***. Warren (1984) showed that leg length related to realizing climbability. Warren and Whang (1987) showed that realization of passability related to shoulder width. Marik (1987) showed that changes in participant's height affected affordances such as sitting and climbing. Bingham and Muchisky (1992) showed that realizing graspability related to hand size. Taken together, these studies provide evidence that humans adjust invariants based on their understandings of their body stature in the environment. Further, Marik's (1987) experiment showed observers can rapidly and accurately adapt to at least some changes in their stature (in this experiment, specifically height), when they become aware of them. Marik varied subjects' height by having them stand and walk on wooden blocks, and showed that subjects realized a different affordance after a period of accommodation. The issue for VE system designers thus becomes whether or not one should somehow represent the physical characteristics of observers in order to engender use of affordances. In terms of Figure 1, this means that a user's understanding of body stature in an environment affects the affordances that the user can realize in the environment. Further, Marik's experiment suggests that physical characteristics have persistence in the stimulus integration mechanism, and do not simply arise from sensory stimuli.

***Affordances depend on the organism's sources of sensory stimuli.*** Different senses result in different affordances. Animals such as bats and dolphins, with strong auditory sensory systems are afforded different things by their environment than animals without auditory systems such as snakes. Stephens and Banks (1987) showed that the ability to detect differences in spatial contrast (crucial to object recognition) changes as infants age, suggesting that changes in underlying neural mechanisms underlie the ability to perceive these differences. As humans inherently use multiple senses to perceive affordances, the issue for VE system designers becomes how to develop multimodal representations that elicit such direct perception in virtual worlds. In terms of Figure 1, this means that the specific senses available, or not available, to the user in a VE bound the affordances that a user may realize in the environment.

***Affordances depend on integration of multimodal sensory stimuli.*** Gibson (1979) recognized the cross modal perception that occurs between vision and kinesthetics, calling it "visual kinesthesia." Van Der Steen (1996) suggests that a multimodal perception model is needed to describe the dynamics of perceived self-motion in a virtual environment. Wertheim (1994) argues that visual-vestibular interaction is crucial for correct perception in ecologically valid environments. Marik (1987) showed that the affordances of sitting and climbing are affected by visual information about chair or step height, and vestibular information about participant's leg length and eye height. One may deduce from such research such that affordances are perceived because of cross modal stimulation, and further that affordances are a way of describing how an organism integrates its knowledge of its own action capabilities. Virtual environment designers need to understand the types of cross-modal interactions that transpire during direct perception and the possible sensory substitution schemes that can be enacted when a critical sense cannot be represented in a virtual world.

The argument that affordances may be cross modal is not prevalent in the affordance literature, which is fixated on visual perception. The present lack of research on multi-sensory perception is unfortunate, because there is evidence that much of perception depends on cross modal sensation. Kalawsky (2000, p.2) states, "Traditionally, sensory modalities have been investigated in isolation from one another." He argues that different kinds of interactions involve different sets of sensory modalities, rather than modalities working in isolation. For example, he suggests that four senses bear on orientation: visual, tactile, proprioceptive, and vestibular.

The premise that the perception of affordances depends on integration of multimodal stimuli could represent a problem for perceiving affordances in present day virtual environments. Indeed, Stappers (1999) showed that the affordance of passability was not correctly perceived in a VE, possibly because shoulder width was not perceived. However, it may be possible to substitute information naturally presented via non-visual modes with that represented via the visual mode in a virtual environment. For example, Runeson and Frykholm (1981) showed that observers could accurately estimate the weight of an object simply by viewing a small number of lights worn on significant points on a human form picking up the object. Therefore, designers may be able to exploit the existing strong correlation between visual (e.g., light points) and non-visual (e.g., the weight of an object) information to replace missing sensory information in a virtual environment. Virtual environment designers thus need to determine the key physiological factors (e.g. eye-height) that drive sensory viewpoint and how to appropriately represent these factors in the virtual world.

This has direct implications for Figure 1, in that a user's integration of body stature, action capabilities, and available sensory modalities also affects the affordances that the user may realize.

***Affordances arise as the organism learns to act within its environment***. Eleanor J. Gibson et al. (1987) showed that transversability of different surfaces for infants depended on the mode of locomotion (crawling or walking) and that the pattern of experimentation to learn what a surface afforded differed between crawlers and walkers. Marik (1987) showed that experience with changed body stature requires a period of accommodation during which the new stature is experienced. Experience arises as the organism explores its environment. These findings have significant implications for the design of virtual environments. New users in a virtual world are comparable to infants, except that they come to the virtual world with a wealth of experience. VE designs that exploit what users have already learned should require less training

Eleanor J. Gibson (1987) argues that there are eight well-substantiated conclusions about perception in infants that have implications for theories of perception.

1) Perception is active, exploratory, and motivated even in the neonate.
2) Perception [in infants] is externally directed toward distal sources of information.
3) Infant perception not only uses but also depends on information given in motion.
4) Perception [in infants] is of a three-dimensional world.
5) Perceptual "constancy" for various object properties exists before reaching, grasping, and handling objects are manifest [in infants].
6) Perception (in infancy) is coherent; that is, structure is detected.
7) Perception [in infants] is inter-modally coordinated.

8) Perceptually guided actions are organized and flexible [in infants], not reflexive or mechanical stimulus-response sequences.

Freedland and Dannemiller (1987) showed that motion–sensitive mechanisms responsive to small spatial displacements are present at five months of age. They conclude that image motion is a rich source of information about the layout of surfaces in an environment. Kellman, Glietman, and Spelke (1987) showed that infants as young as 16 weeks distinguish optical displacements given by their own motion from displacements given by moving objects, and use only the latter to perceive the unity of partially occluded objects. They asserted that object perception therefore depends on registration of the motion of surfaces in a three-dimensional layout. Kellman and Short (1987) showed that continuous perspective transformations, given by object or observer movement, are the information basis for early three-dimensional form perception. Detecting form in stationary views is a later development. Kourtzi and Shiffrar (1997) for example argue that motion plays a crucial role in object recognition. In terms of Figure 1, this means that there is a feedback loop from decision-making and execution based in experience that affects the affordances that can be realized.

The conclusion drawn on the foregoing discussion is that affordances are realized through integration of environmental stimuli and state stimuli interacting with experience gained through decision making, which in turn affects an individual's knowledge of internal state, action capabilities, and body stature in the environment, just as illustrated in Figure 4.

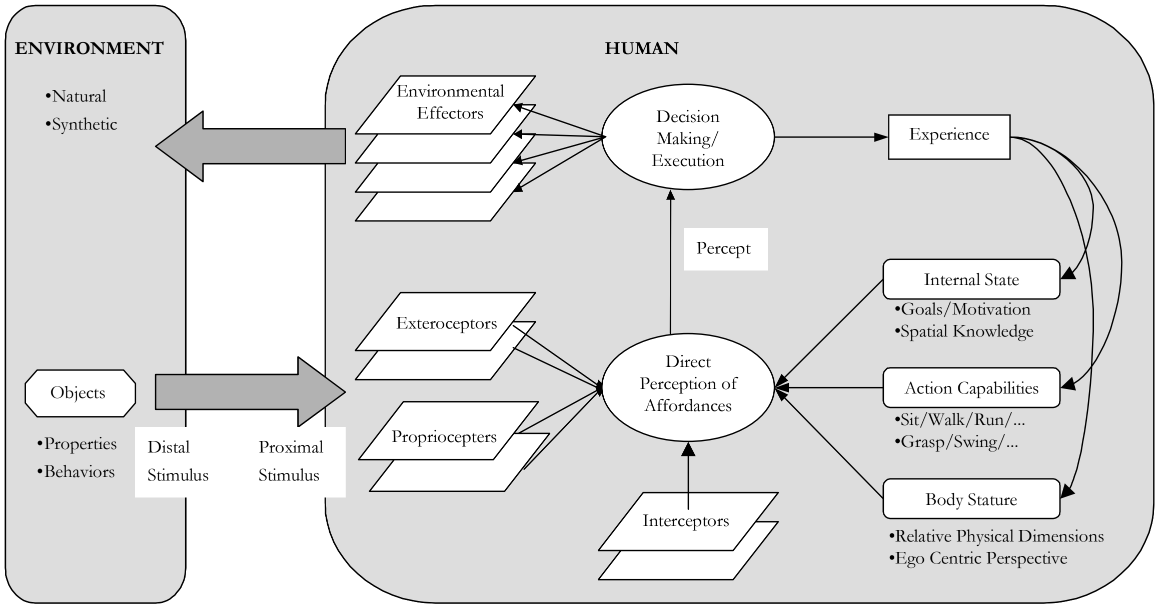


Figure 4: Realization and exploitation of affordances.

### Realization Failures

Affordances are not correctly realized in all circumstances, even in the natural environment. Gibson (1979) discusses this problem in the context of illusions, and defined circumstances that do not permit the correct perception of affordances as ecologically invalid. Ecological invalidity may be said to be a violation of the environment (Kennedy, 1974). Designed environments, such as VEs, are not intrinsically ecologically valid, and so may not support the realization of affordances as desired by their designers. While researchers have discussed the problem of ecological invalidity in general terms, Figure 4 presents a context for decomposing the causes of such invalidity and thus, in turn, discovering guidance for VE designers.

The most basic source of failure to realize affordances is an inaccurate or insufficient sensory stimulus, i.e., one below the modality's response threshold (see Figure 2). Rose, Jankowski, and Senior (1997) showed that infants are capable of recognizing line drawings missing as much as 66%

of their contour. In this same study, infants failed to discriminate between two extremely impoverished figures, i.e. more than 66% missing, because of inaccurate sensory stimuli. Thus, to realize the perception of affordances, stimuli must be above the appropriate sensory modality threshold. In terms of Figure 4, this would be a failure of the proximal stimuli to activate the sensory system.

A closely related source of realization failure that is especially pertinent to VEs is the absence or inaccuracy of required multimodal sensory stimulation to realize an affordance. The realization of affordances can depend on multimodal sensory stimulation. For example:

- Warren and Whang (1987) found in a study of passability, that when approaching a doorway whose ratio of width to shoulder width was less than 1:1.3 that subjects would rotate their body. This is an indication of the kinesthetic and visual sense interacting with the action of walking.
- Wertheim (1994) argues that the vection created with an optokinetic drum must involve extra retinal signals, namely vestibular afferents. This argument led Wertheim to argue more generally that visual-vestibular interaction is crucial for correct perception in ecologically valid environments.
- Oudejans et al. (1996) presented a study on the catchability of fly balls measuring the ability of subjects to judge whether they could catch balls thrown at various distance from the subject. This study demonstrated that perceiving the affordance of catchability depends on kinematics of the subject's body, as well as the movement of the ball, by showing that the ratio of balls judged catchable to those actually catchable varied with the dynamic information available to the observer. Subjects' judgment error was almost halved when the subjects were permitted to move before judging a ball as catchable. This suggests that the judgment as to a

ball's catchability depends on dynamic information arising from the kinesthetic and vestibular senses, as well as information arising from the visual sense.

All of this research suggests that correct realization of these affordances may be perceived cross modally, in particular crossing between the visual sensory system and other sensory systems (e.g., vestibular, kinesthetic). This poses a problem for VE design because even though their stimulation is required for realization of some affordances, there exists no reliable and economical way of providing artificially simulated propriocepters and interceptors (Stuart, 1996). Instead of receiving artificial simulation correlated with the virtual environment, users experience continual and generally contradictory stimulation from the natural environment. In terms of Figure 4, this would be a breakdown of the interface between propriocepters and interceptors and direct perception.

Another source of realization failure may be inadequate perception of body stature in the environment. Gibson (1979) suggested that environmental properties have to be measured relative to the animal, without specifying how this relationship is defined. Warren (1984) argues that this is a visual perception, however acknowledges that what must be occurring is perception of environmental properties relative to the observer's capabilities. He proposed that the critical (maximum) and optimal values of an environmental property, relevant to performing an action, are an invariant proportion of some aspect of the actor's body scale. He demonstrated this by showing that the climbing affordance on stairs is influenced by visual information about the height of the step and internal state information about the length of the observer's leg. Marik (1987) extended Warren's finding by demonstrating that the critical boundaries for the affordances of sitting and stair climbing are scaled with reference to the actor's eye-height. Warren and Whang (1987) found that perception of the passage affordance depends on both visual information about aperture width and internal knowledge of shoulder width. This study presented doorways of varying widths to subjects, and measured their response. At shoulder widths to doorway ratios of less than 1:1.3, subjects perceived insufficient clearance, and rotated their bodies to proceed through the opening. These findings are significant for understanding how affordances may be perceived in VEs, because it indicates that information about body stature is required if a user is to realize correct affordances, and because VE designs frequently do not provide users with information about their own stature (Anders, 1999). In terms of Figure 4, this would be a loss of the information represented by "stature" in the environment block.

A final source of realization failure particular to designed environments such as VEs is inadequate perception of action capabilities in the environment. For example, VEs often do not match the real world in terms of what can be done. Indeed providing different action capabilities is one of the motivations for using virtual environments. Although VEs can evoke an immersive experience, this does not lead automatically to a natural interface. To experience a natural interface, the user should be able to perceive what could be done via the interface. St. Amant (1999, p. 342) for example argues that:

> "Users only rarely encounter problems in using specific widgets, and remedies at the given level of abstraction can only provide a limited benefit. Problems more often arise at a conceptual level. What is it possible to do in the interface? Why can't a given operator be executed in the current state? How can one reach a desired goal? "

Since VEs represent a kind of reality and seek to immerse their users in that reality, users have a reasonable expectation that the environment behaves like reality or in easily understandable deviations from reality. However, the VE interface design, not physics, defines what the organism is capable of doing (moving, orienting…), thereby defining the context for affordances included in the environment. In the example of the passability affordance study (Warren & Whang, 1987), it is not clear that a VE user would know that body rotation is possible in any particular interface, much less necessary or helpful to gain passage. In the example of the catchability study (Oudejans et al., 1996), it is possible that VE users may not know how to maneuver so as to catch something if locomotion is represented radically different from the nature environment.  As a result, users cannot depend on their experience based expectations about manipulating their environment.  In terms of Figure 4, this would be a loss of the information represented in the action capabilities block.

Figure 5 illustrates these potential breakdowns in the realization of affordances in virtual environments.  To summarize, the types of realization failures that may occur in VE include:

1) Inaccurate or insufficient sensory stimuli,
2) Absence or inaccuracy of required multimodal sensory stimulation,
3) Inadequate perception of body stature in the environment, and
4) Inadequate perception of action capabilities in the environment.

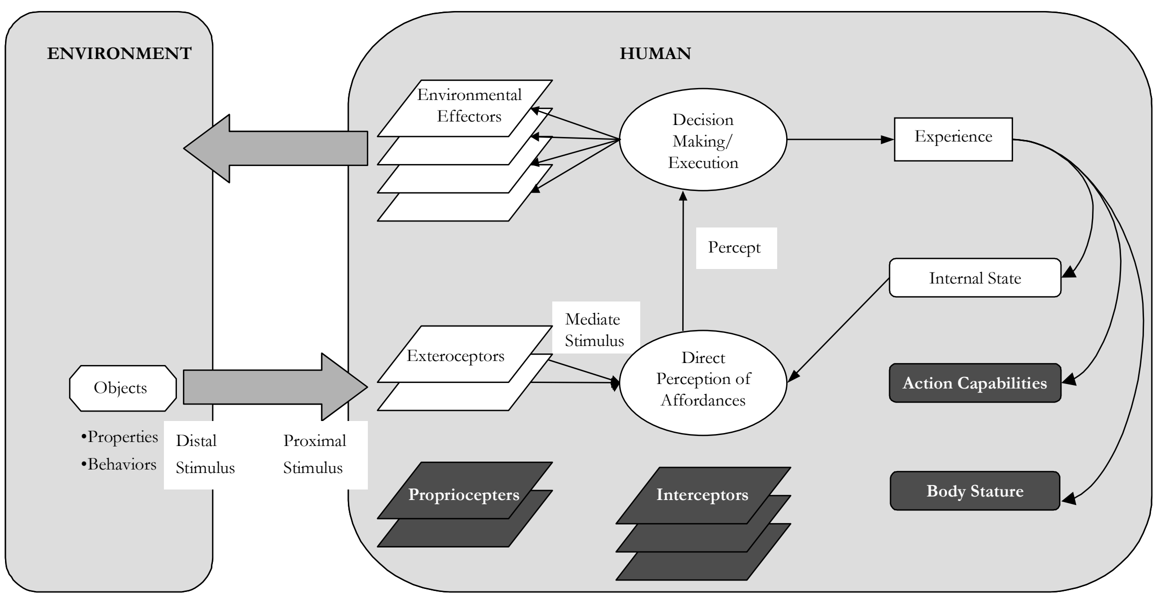


Figure 5:  Potential failures in realizing affordances in virtual environments.

## Sensory Substitution via Affordance-Based Designs

Breakdowns in the realization of affordances in VEs can potentially be overcome by 1) correlating sensory stimuli to the experience represented in the virtual world, 2) determining a particular modality is irrelevant to the experience, or 3) substituting information in another modality for missing modalities. The latter approach, sensory substitution schemes, may have the greatest potential as it is not limited by technology (as is the first approach) and does not require diminishment of an experience (as does the second approach). Sensory substitution schemes could potentially be used to replace missing stimuli required to evoke the realization of affordances. VEs create an artificial world, whose design defines what the user can do and the sensory stimuli to be provided. As such, VEs provide some but not all of the sensory stimuli of reality. Non-visual mode stimuli in particular are missing in VEs (e.g., kinesthetic, vestibular). As a result of these inaccuracies and absences, a user's ability to correctly perceive available action capabilities (what the user can do in the environment) may be depleted. Furthermore, representations of user characteristics (e.g., size, strength) that would normally be understood through kinesthetic and vestibular stimuli are arbitrary and typically unrelated to the user's "real" capability. VE designers, by selecting action capabilities to support and object/properties/behaviors to represent, can choose which affordances the VE will present. However, this process is often not deliberate. Thus, it is important to note that the VE, like any other environment, will present affordances whether or not they are consciously designed.

It may be possible to provide missing non-visual sensory stimuli, and hence enable perception of specific affordances by manipulating the objects/properties/behaviors selected for representation in a virtual environment. More specifically, it may be possible to realize correct perception by overloading (i.e., above threshold) visual stimuli that enable perception of particular affordances.

## Evidence that Sensory Substitution Schemes Can Succeed

There is evidence that sensory substitution schemes can lead to correct perceptions, even though the current state of multimodal modeling in VE design is rudimentary (Popescu et al., 2002). First, consider that all perception is multimodal, not just complex reactions to an environment (Storms, 2002). Bregman (1990) believes that auditory and visual modalities interact in order to specify the nature of certain events within a perceiver's environment. Eimer (2001) asserts that cross-modal links exist in spatial attention between vision, audition, and touch, and that emerging evidence suggests that cross modal links in spatial attention affect sensory-perception stages, but have less impact on later post-perceptual stages. The body of evidence in the literature clearly indicates that under certain conditions, auditory-visual perceptual phenomena do exist (Storms, 2002). The implication for the present study is that since sensory modalities are complementary, they may be to some extent redundant and therefore replaceable by stimuli in other modalities.

Next, consider the evidence that there may be underlying neurological factors that determine perception more than the specific sensory modalities involved. Specifically, if the brain is structured to favor perceptions arising from multimodal stimuli, then correct perception may depend on multimodal stimuli. Stein and Meredith (1993, p. 172) found neurological evidence for this position, based primarily on their study of cats. They conclude:

> "... the spatial register among the receptive fields of multisensory neurons and their temporal response properties provide a neural substrate for enhancing responses to stimuli that co-vary in space and time and for degrading responses that are not spatially and temporally related."

The implication for the present study is that since brain structure may be favorable toward perception of multimodal stimuli, then in environments where specific sensory modalities are impoverished such as VEs, correct perception may require stimuli that substitute for improvised modalities.

Next, consider that there is evidence that stimulation in one modality can complement or distract from stimulation in other modalities. Curran et al. (1999) provide evidence for cross modal priming, specifically that verbal data primed the perception of subsequent visual images. Henneman and Long (1954) indicate there has been very little experimental evidence comparing audition and vision as channels for data presentation and conclude that most auditory-visual inter-sensory studies have focused on sensory thresholds as opposed to supra-threshold levels that typify actual perceptual phenomena. Rode et al. (2001) showed that an audio distraction significantly lowered perceived pain, as measured by subjective report and improvement on a muscle stamina task. Spence and Driver (1997) argue that people can monitor cross modal stimuli as effectively as a single stimulus. The implication for the present study is that the ability for stimuli in some modalities to distract from stimuli in other modalities suggests that cross modal sensory substitution schemes can be an effective HCI approach, within yet to be determined limits.

Finally, Shimojo and Shams (2001) note that the direction of cross-modal interactions has been thought to be determined by the relative appropriateness of the modalities involved in a given task, but that emerging evidence is that the direction depends at least in part on the structural (spatial versus temporal) nature of perceived stimuli. They, along with other researchers such as Monder and Amirault (1998), note the strong association between spatial perceptions and visual stimuli, and temporal perceptions and auditory stimuli. Shimojo and Shams (2001) suggest that the brain may accept stimuli in a modality other than the natural one, if the underlying spatial-temporal structure of the stimuli is retained. This is similar to the argument in favor of stimulus-response compatibility advanced in for example Eberts (1994). In general, relationships between stimuli and responses are compatible when they facilitate correct action. The example cited in Eberts is for a stovetop design, in which the controls are laid out in the same pattern as the stove eyes. The implication for the present study is that substitution schemes should match stimuli to the spatial-temporal nature of perception when substituting one modality for another.

The foregoing discussion presents the general case that substitution schemes may succeed, however, the specific form of the substitution scheme has not been considered.

### Determining which Sensory Substitution Schemes to Explore

There are many different conceivable sensory substitution schemes; however, the literature provides some guidance on which is likely to succeed. First, consider that the only mechanism that a VE designer has for communicating with users is through the proprieties of objects represented in the virtual environment. Therefore, the only possible sensory substitution schemes will be ones that exploit the exterocepter (i.e., vision, audition) or propriocepter (i.e., cutaneous, gustation, olfaction) sensory systems.

The most obvious scheme would be to provide visual cues to substitute for missing sensory stimulation. This is because:

1) Visual stimuli in VEs are already available and powerful,
2) The visual sensory system has the broadest band input to the brain (Sharma et al., 1998), and
3) The visual dominance effect.

Storms (2002) suggests that substitution schemes based on visual cues should be readily perceived. Unless there are significant differences in the intensities of information gathered via different modalities, visual stimuli have been found to have a greater influence on perception via other modalities, as compared to the influence of other modalities on the visual sense (Stein & Meredith, 1993). Wickens (1992, p.108) explains visual dominance by stating: "if visual stimuli are appearing at the same frequency and providing information of the same general type or importance as auditory or propriocepter stimuli, biases toward the visual source at the expense of the other two (auditory and propriocepter) will be expected." Cohn et al. (2000) present an example of how a visually pure environment can elicit a visual reflex rather than a straightforward perception of the sensory data. More specifically, they showed that visual information about body motion alone is sufficient to elicit directionally appropriate Coriolis compensations (i.e., the automatic compensation made in reaching that counters Coriolis effects). Srinivasan, Beauregard, and Brock (1996) demonstrated the effect of visual dominance on haptic perception. In this experiment, participants had to discriminate the stiffness of two virtual springs when provided with independent visual and haptic feedback about their stiffness. When visual stiffness stimuli conflicted with haptic stiffness stimuli, participants judged stiffness consistent with the visual stimuli in preference to haptic feedback. Finally, Ivanenko et al. (1998) showed that humans exposed to a VE undergo adaptations at the sensory level including adaptations of the vestibulo-ocular reflex and angular displacement perception, and that these adaptations may be independent. This evidence that visual stimuli can evoke a reaction in other sensory systems, suggests that visual stimuli alone may evoke a perception comparable to that evoked by multimodal stimuli in the natural environment.

However, vision is not the dominant sense in every circumstance; therefore substitution schemes other than purely visual stimuli should be considered. During signal detection (temporal in nature and typically associated with sustained attention or vigilance), the auditory channel proves dominant over the visual channel, which is why warning signals are typically produced with auditory devices (Storms, 2002). There is also evidence that the intensity of visual images can be enhanced by audio stimuli (Shimojo & Shams, 2001). It is known that the presentation of an audio cue reduces the time required for visual searches (Flanagan, McAnally, Martin, Meehan, & Oldfield, 1992). This suggests that tasks thought of as primarily dependent on visual perception may be further enabled by auditory perception.

What about sensory substitution schemes exploiting propriocepters? There is very little research into providing sensory stimulation for gustation and olfaction, but somewhat more for haptic stimulation. Proffitt and Kaiser (1995) provide an example of haptic dominance. They asked participants to estimate the incline of a hill while provided with audio, visual, and haptic stimuli, and the most accurate estimates resulted from the haptic. In general however, there is little evidence encouraging approaches exploiting propriocepters (Popescu et al., 2002). Therefore, sensory substitution schemes may best be based on exterocepters (i.e., visual, auditory), instead of propriocepters.

A final potential substitution scheme, in addition to visual, audio, and haptic, is a combined approach. Several authors have suggested that sensory substitution schemes should map spatial information to visual substitution cues, and temporal information to auditory cues (Popescu et al., 2002; Shimojo & Shams, 2001). This suggests that the structure of the information to be perceived might indicate the best substitution scheme.

Figure 6 illustrates the fundamental constraint of any sensory substitution scheme, namely that the substitution stimuli can only arise from the properties and behaviors of objects represented in the virtual environment. In addition, the substitution stimuli in successful sensory substitution schemes must:

- Replace sensory modalities not represented in the virtual environment,
- Outweigh natural stimuli not correlated with the virtual environment,
- Exceed response thresholds in the modality used for the substitution.

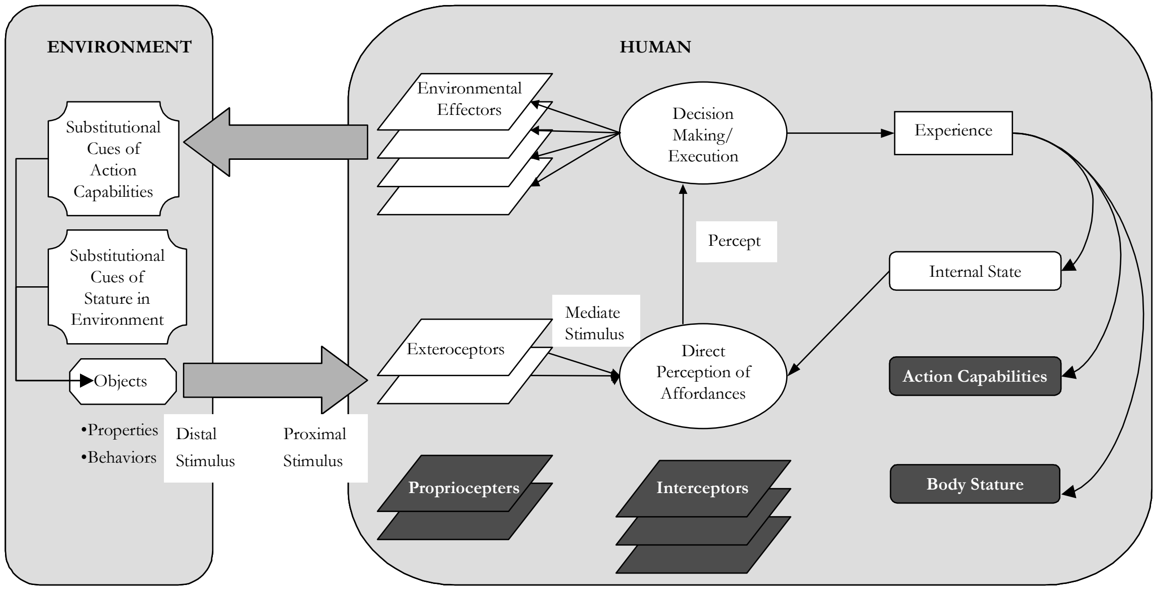


Figure 6: A conceptual model for VE designs enabling the realization of affordances.

One way to select a substitution scheme is to test it to see if it enables correct perception, in terms of enabling the realization of affordances. There are a large number of conceivable affordances against which sensory substitution schemes could be tested for enabling correct perception. Instead of considering every one of them, it is possible to reduce the number that should be considered to a reasonable few, based on the understanding of affordances developed in the foregoing discussion. Recall Shaw, Flascher, and Kadar's (1995) classification of affordances as geometric (sized to body characteristics such as stature) or kinetic (sized to action capabilities). This suggests that a good test suite of affordances should include at least one geometric and one kinetic affordance. Further, since one of the chief advantages of VEs is that they can enable body statures and action capabilities that do not occur in the natural environment, the test suite should include unnatural body statures and action capabilities, e.g., flying. This suggests a test suite of three affordances:

1) Passability

2) Catchability

3) Flyability

**Realization of Passability**

A critical component of learning to act within an environment is exploration, which requires wayfinding through the environment (Gibson, 1979). Further, as users often become lost while exploring a VE (Ellis, 1993; Jul & Furnas, 1997), some means of better affording wayfinding may substantially enhance VE task performance. In contrast, Cutting et al. (1999) assert that wayfinding through situations in the natural environment quickly and safely is a basic and routine task. Passability, the realization that a passageway affords movement by the human through it, is a basic affordance required for wayfinding through cluttered environments. Warren and Whang (1987) conducted a series of experiments measuring participants' responses to various passageway sizes. They determined that the invariant for free walking passage was the ratio of passageway width to shoulder width. The critical value, i.e. value at which behavior changed from free walking to rotation of shoulders, was 1:1.3, which defines an invariant in terms of body stature.

It is not evident that VEs enable the realization of passability. Stappers (1999) for example found no evidence that users in a VE rotated their shoulders in response to various passage widths as Warren and Whang (1987) found in the natural environment. This failure to realize passability is anticipated because of impoverished, absent, or conflicted cues in VEs as shown in Figure 5. The stimulation integration process depends on three key sources of information in order to realize the passability affordance. First, a goal or motivation to move must exist. Next, visual stimulation arising during the process of locomotion must provide sufficient stimulation of a passageway. Finally, knowledge of body characteristics, or ongoing kinesthetic and vestibular stimulation, must provide information about body stature. The stimulus integration mechanism arrives at the percept of the passability affordance by scaling shoulder width to passage width, when motivated by the goal to move through the passage. The realization of the passability affordance can be detected by observing the decision made by a subject when arriving at a passage entrance, either to:

- proceed without rotation (ratio is > 1:1.3), or
- rotate (ratio < 1:1.3), or
- stop (ratio < some unknown small value)

As Table 5 indicates, three key sources of information for realizing the passability affordance are available in a natural environment, but information about body stature is impoverished in a virtual environment. A VE user's sense of their body stature, which arose through experience in the natural world, is not valid in the virtual world. Sensory systems such as propriocepters and interceptors that a user might use to develop kinesthetic or vestibular information about body stature in an environment are not available to users in typical VEs and further, users may be provided with conflicting information from their stature in the natural environment.

Table 5: Information required for the realization of passability.

| **Required information** | **Enabling information in the natural environment** | **Enabling information in a virtual environment** |
|---|---|---|
| Desire to move through passage | Internal state information which includes goals, motivation | Internal state information which includes goals, motivation |
| Passage width | Visual | Visual |
| Shoulder width | Arises from experience and ongoing kinesthetic and vestibular mode stimulation | Impoverished, absent, and/or conflicted in a VE |

Impoverished, absent, or conflicted information needed to realize the affordance of passability in a VE might be provided by a sensory substitution scheme. To be effective, the substitution would have to replace missing exterocepters (i.e., visual, auditory cues), interceptors (i.e., kinesthetic, vestibular cues), and propriocepters (i.e., cutaneous cues) associated with traversal through a passageway, as well as overwhelm any conflicting cues from the natural environment. Due to visual dominance (Storms, 2002) and the strong association between spatial perception and visual stimuli (Shimojo & Shams, 2001), visual cues for body stature may be able to substitute for absent multimodal sensory stimulation and body stature information, thereby enabling the realization of the passability affordance in virtual environments.

Visual dominance refers to the preeminent influence that visual stimuli have on perceptions. Stein and Meredith (1993) note that unless stimuli in a competing sensory modality are especially intense, visual stimuli provide the basic influence as to how sensory stimulation are interpreted. Thus, it may be possible to leverage a visual cue representing shoulder width to dominate other sensory stimulation, such as kinesthetic and vestibular cues about stature in the natural environment, by exploiting the visual dominance effect. In a similar vein, since passability is a geometric affordance, its realization is enabled by a spatial perception, namely the comparison of shoulder width to passage width. Popescu et al. (2002) notes the strong correlation between visual stimulation and spatial perceptions. A visual cue representing shoulder width would exploit the relationship between spatial perception and visual stimuli.

In terms of the realization process described for passability, such a visual cue in a VE would provide the impoverished, absent or conflicted information about body stature in the virtual environment. The visual cue could potentially provide a valid source of information about the user's body stature. Armed with this additional information, a user's stimulus integration mechanism would arrive at the percept of the passability affordance by scaling the visual cue about shoulder width to passage width, when motivated by the goal to move through a passage. Visual cues then, for the specific affordance of passability, may be able to meet the previously described requirements for a successful sensory substitution scheme: replacing sensory modalities not represented in a VE by exploiting the visual dominance effect, outweighing natural stimuli not correlated with the VE; and exceeding response thresholds in the modality used for the substitution. These observations lead to the following hypothesis.

**Hypothesis**: Visual cues for body stature substituting for absent multimodal sensory stimulation and body stature information can enable the realization of the passability affordance in VEs, as confirmed by testing for the ratio of 1:1.3 for comfortable passability.

It is not evident what form these visual cues should take. While Warren and Whang (1987) assert that shoulder width is the required body stature information to realize passability, they and other researchers such as Marik (1987) suggest that realization of the affordance may be scaled to other body stature information such as eye height. Also, it is possible that a combination of body stature information is required (e.g., shoulder width, eye height). Finally, it is not known how extensive the cue would have to be, in terms of visual thresholds. For example, if the cue is a representation of shoulder width, it is not known whether the cue has to be a realistic representation of shoulders on a body form, or a simple cross bar on a stick. These open questions raise the need to identify which visual cues of body stature provide the most effective substitution for realization of passability.

**Hypothesis**: An appropriate minimal form for visual cues of body stature can be found, as confirmed by measuring threshold responses to a variety of cues.

## **Realization of Catchability**

A critical ability in any environment is interaction with other moving objects, whether animate or inanimate (Gibson, 1979). As an example, Oudejans et al. (1996) investigated the affordance of catchability, in the particular situation when movement is required to intersect an object's path, as opposed to simply reaching. They demonstrated that realization of this kinematic affordance depended on knowledge of action capabilities, in contrast to previously demonstrated geometric affordances, such as passability, that depend on knowledge of stature in the environment. Oudejans et al. demonstrated that the specific kinematic action capability information required was knowledge of self-locomotion, namely velocity and acceleration. This study found that the ratio of the range at which balls were actually catchable to the range at which balls were judged catchable was 1:1.2, which is a measure of the subject's perception. An observer can realize catchability if the observer can scale the action capability of self-acceleration to the object's motion, as opposed to scaling the body stature, i.e., of shoulder width to the passage width, as was the case for passability. Catchability depends therefore not only on spatial but also temporal relationships.

It is not evident that VEs enable the realization of catchability. Indeed, the failure to realize catchability is anticipated because of impoverished, absent, or conflicted cues in VEs as shown in Figure 5. The stimulation integration process depends on seven key sources of information in order to realize the catchability affordance. First, a goal or motivation related to catchability must exist, for example a desire to catch a ball. Next, sensory stimulation in the environment must provide information about the ball's position, velocity, and acceleration. Acceleration is negligible assuming un-powered flight and short flights where air resistance is not a factor. Next, sensory stimulation in the environment and in the subject must provide sufficient indication of self-position, self-velocity, and self-acceleration, so that the subject may move toward the ball's path. The stimulus integration mechanism arrives at the percept of the catchability affordance by scaling the self-acceleration action capability to the vertical optical acceleration of the ball. Vertical optical acceleration is the acceleration of the projection of the center of the ball on a vertical image plane, and specifies the direction that the observer should accelerate to intercept the ball's flight. Catchability is realized when a near zero vertical optical acceleration can be achieved, when motivated by the goal to catch the ball. Near zero acceleration means acceleration below the detection threshold. Note here that the affordance under consideration is catchability, which is a judgment as to whether a ball is catchable or not, not the actual hand-eye coordination of grasping a ball in flight. The realization of the catchability affordance can be detected by observing the decision made by a subject when presented with thrown balls, either to continue to pursue catching the ball, or to stop.

Table 6 indicates that seven key sources of information for realizing the catchability affordance are available in a natural environment, but information about self-acceleration is impoverished in a virtual environment. A VE user's sense of action capabilities, which arose through experience in the natural world, is not valid in the virtual world. Sensory systems such as propriocepters and interceptors, which a user might use to develop kinesthetic or vestibular information about action capabilities in an environment, are not available to users in typical VEs and further, users may be provided with conflicting information via kinesthetic and vestibular senses from the natural environment.

Table 6: Information required for the realization of catchability.

| **Required information** | **Enabling information in the natural environment** | **Enabling information in a virtual environment** |
|---|---|---|
| Desire to catch the ball | Internal state information which includes goals, motivation | Internal state information which includes goals, motivation |
| Ball position | Visual and Auditory | Visual and Auditory |
| Ball velocity | Visual and Auditory | Visual and Auditory |
| Ball acceleration | Visual and Auditory | Visual and Auditory |
| Self-position | Visual | Visual |
| Self-velocity | Arises from experience and ongoing kinesthetic and vestibular mode stimulation | Impoverished, absent, and/or conflicted in a VE |
| Self-acceleration | Arises from experience and ongoing kinesthetic and vestibular mode stimulation | Impoverished, absent, and/or conflicted in a VE |

As was the case for passability, impoverished, absent, or conflicted information needed to realize the affordance of catchability in a VE might be provided by a sensory substitution scheme. To be effective, the substitution would have to replace missing exterocepters (i.e., visual, auditory cues), interceptors (i.e., kinesthetic, vestibular cues), and propriocepters (i.e., cutaneous cues) associated with accelerating to catch a ball, as well as overwhelm any conflicting cues from the natural environment. Due to visual dominance (Storms, 2002), the ability for auditory stimuli to intensify visual stimuli (Shimojo & Shams, 2001), and the strong association between temporal perception and auditory stimuli (Shimojo & Shams, 2001), a combination of visual and audio cues for action capabilities may be able to substitute for absent multimodal sensory stimulation and action capability information, thereby enabling the realization of the catchability affordance in virtual environments.

Visual cues representing self-velocity and self-acceleration may dominate other sensory stimulation, such as kinesthetic and vestibular cues about self-acceleration in the nature environment, by exploiting the visual dominance effect. Since both self-velocity and self-acceleration have a time component, they are temporal perceptions. Storms (2002) and Popescu et al. (2002) note the strong correlation between temporal perception and auditory stimulation. Auditory cues representing self-acceleration and self-velocity would exploit the relationship between temporal perception and auditory stimuli. Finally, a combination of visual and auditory cues could exploit the reinforcing and intensifying effect between visual and auditory stimuli noted by Shimojo and Shams (2001), and thereby may enable realization of the catchability affordance.

In terms of the realization process described for catchability, visual and auditory cues in a VE would provide impoverished, absent or conflicted information about self-position in the virtual environment. In addition, visual and auditory cues could potentially be combined to provide a valid source of information about a user's action capability. Armed with this additional information, a user's stimulus integration mechanism would arrive at the percept of the catchability affordance by scaling cues about locomotion action capabilities, when motivated by the goal to catch the ball. Visual and auditory cues then, for the specific affordance of catchability, may be able to meet the previously described requirements for a successful sensory substitution scheme: replacing sensory modalities not represented in a VE by exploiting the visual dominance effect, outweighing natural stimuli not correlated with the VE; and exceeding response thresholds in the modality used for the substitution. These observations lead to the following hypothesis.

**Hypothesis**: Visual and auditory cues for acceleration and velocity substituting for absent multimodal sensory stimulation and action capabilities information can enable the realization of the catchability affordance in VEs, as confirmed by testing for the 1:1.2 ratio of actually catchable balls to those perceived catchable.

It is not evident what form these visual and auditory cues should take. Specifically, it is not known how extensive the cue would have to be, in terms of sensory system thresholds. For example, if the visual cue is a representation of body lean, it is not known whether the cue has to be a realistic representation of a body form, or a simple cross bar on a stick. Likewise, it is not known how intensive auditory cues would have to be to realize correct temporal perception. These open questions raise the need to identify which visual and auditory cues for locomotion provide the most effective substitution for realization of passability.

**Hypothesis**: An appropriate minimal form for visual and auditory cues of locomotion can be found, as confirmed by measuring threshold responses to a variety of cues.

**Realization of Flyability**

Flyability is not an action capability of humans in the natural environment, but its inclusion in the VEPAB indicates it is frequently provided as a capability in virtual environments (Lampton et al., 1994). Since flyability is not a natural action capability, there are no studies that suggest geometric or kinematic relationships on which flyability would depend. In fact, realization of flyability would only arise when a specific set of environmental effectors related to this capability is specified, and when experimentation leads to an understanding of this action capability (Gibson & Pick, 2000). Recall that Gibson et al. (1987) showed that the transversability of different surfaces depended, for infants, on the mode of locomotion (crawling or walking), and that the pattern of experimentation to learn what a surface afforded differed between crawlers and walkers. New VE users are comparable to infants, except that they come to the virtual world with a wealth of possibly misleading experience. Of course, since VEs are not required to conform to the laws of physics, no specific environmental effectors are required to enable users to fly in a virtual environment. Users would become aware of the possibility of flying, just as babies become aware of the possibilities of crawling and walking, through a process of experimentation with their environment effectors based on sensory stimulation, leading to experience that such locomotion modes are possible.

Once a VE user is aware that flying is possible, then the realization of the flyability affordance is much the same as realizing the affordance of any other form of locomotion such as crawling, walking, or running. That is, its realization will involve the integration of some combination of environmental and self-stimuli in the context of some goal or motivation. Thus the stimulus integration mechanism can be seen as finding the best-fit mode within the constraints of the environment while realizing a locomotion affordance. Gibson et al. (1987) noted that the environment specifies information about space available and the surface that the human uses in realizing the affordance of various forms of locomotion. For example, Warren (1984), in his study of stair climbing, determined that the critical ratio of leg length to stair height, the point at which subjects shifted from normal stair stepping to crawling, was also the point at which shifting locomotion modes became more efficient in terms of energy expected. Kelso (1995) provides an in depth consideration of how energy consumption relates to locomotion mode chosen.

Since flyability is not an affordance of the natural environment, it is obvious that VEs do not intrinsically enable the realization of this affordance. This failure is a direct result of impoverished, absent, or conflicted cues that relate to the flying action capability in VEs as shown in Figure 5. Enabling realization of flyability would involve providing sensory substitution stimuli about specific environmental effectors and body stature properties, which combine to create the action capability of flying. Such stimulation integration would depend on seven key sources of information in order to realize the flyability affordance. First, goals or motivations to fly must exist. In the VEPAB documented in Lampton et al. (1994), windows and elevators enabling level changes create this motivation. Next, sensory stimulation in an environment must provide information about the space available. Next, sensory stimulation about the user must provide information about the spatial requirements of the specified flying action capability. For example, if wings are the environmental effectors that relate to flying action capability, then there must be sufficient space to extend and flap the wings. The stimulus integration mechanism would arrive at the percept of the flyability affordance by scaling space availability to the space required for flying action in the context of a motivation to fly. The realization of the flyability affordance can be detected by observing the decision made by a subject when presented with the choice to walk or fly toward a goal. Table 7 summarizes the sources of information required to realize flyability.

Table 7: Information required for the realization of flyability.

| **Required information** | **Enabling information in a virtual environment** |
|---|---|
| Desire to fly | Internal state information which includes goals, motivation |
| Spatial constraints of room | Visual |
| Spatial requirements for flying | Impoverished, absent, and/or conflicted in a VE |

As was the case for passability and catchability, impoverished, absent, or conflicted information needed to realize the affordance of flyability in a VE might be provided by a sensory substitution scheme. To be effective, the substitution would have to replace missing exterocepters (i.e., visual, auditory cues), interceptors (i.e., kinesthetic, vestibular cues), and propriocepters (i.e., cutaneous cues) associated with accelerating to flying, as well as overwhelm any conflicting cues from the natural environment. Due to visual dominance (Storms, 2002), and the strong association between spatial perception and visual stimuli (Shimojo & Shams, 2001), visual cues for action capabilities may be able to substitute for absent multimodal sensory stimulation and action capability information, thereby enabling the realization of the flyability affordance in virtual environments.

Visual cues representing space requirements of the environmental effectors for flying may dominate other sensory stimulation, such as kinesthetic and vestibular cues about self-acceleration in the nature environment, by exploiting the visual dominance effect. In addition to visual dominance, as aforementioned, many researchers (Shimojo & Shams, 2001; Popescu et al., 2002) have noted the strong association between visual stimuli and spatial perception. Since flyability is a spatial perception, visual cues could exploit this strong correlation.

In terms of the realization process described for flyability, visual cues in a VE would provide impoverished, absent or conflicted information about flying action capability in the virtual environment. Armed with this additional information, a user's stimulus integration mechanism would arrive at the percept of the flyability affordance by scaling information about space available constraints to the space required for flying, when motivated by the goal to fly. Thus, visual cues, for the specific affordance of flyability, may be able to meet the previously described requirements for a successful sensory substitution scheme: replacing sensory modalities not represented in a VE by exploiting the visual dominance effect, outweighing natural stimuli not correlated with the VE; and exceeding response thresholds in the modality used for the substitution. These observations lead to the following hypothesis.

**Hypothesis**: Visual cues for space required to fly substituting for absent multimodal sensory stimulation and action capabilities information can enable the realization of the flyability affordance in VEs, as demonstrated by users choice of flying when presented with multiple, valid forms of locomotion.

It is not evident what form these visual cues should take. First, the cues should relate to the environment effectors that enable flying capability. Further, it is not known how extensive the cue would have to be, in terms of visual thresholds. For example, if the visual cue is a representation of body size, it is not known whether the cue has to be a realistic representation of a body form, or a simple rectangle. These open questions raise the need to identify which visual and auditory cues for locomotion provide the most effective substitution for realization of flyability.

**Hypothesis**: An appropriate minimal form for visual cues for flying can be found, as confirmed by measuring threshold responses to a variety of cues.

Chapter 3 provides details of the proposed method by which the present research will test the stated hypotheses.

# CHAPTER 3: METHOD

The method used to evaluate the hypotheses is an experimental program. The following discussion defines the participant population, apparatus, tasks, procedure, VE, and experimental design used in the experimental program.

## Participants

Participants for the experiments were Boeing company employees (54 males, 15 females). All participants completed a demographic survey, the results of which are summarized in Table 8. The number of responses does not always sum to the same total because some participants chose not to respond to particular questions.

Table 8: Demographics of participants.

| **Factor** | **Response** | | | | | |
|---|---|---|---|---|---|---|
| Age | Average | 41.71 | Std Dev | 10.41 | | |
| Gender | Female | 15 | Male | 54 | | |
| Height (inches) | Average | 69.80 | Std Dev | 3.73 | | |
| Color Blind | No | 66 | Yes | 3 | | |
| TV Signals Problem | No | 69 | Yes | 0 | | |
| Normal Vision | No | 44 | Yes | 25 | | |
| Vision Correction | No | 3 | Yes | 41 | N/R | 25 |
| Using Now | No | 11 | Yes | 36 | N/R | 22 |
| Unusual Vision | No | 36 | Yes | 6 | N/R | 27 |
| Normal Hearing | No | 8 | Yes | 61 | | |
| Hearing corrected | No | 5 | Yes | 3 | N/R | 61 |
| Wearing correction | No | 5 | Yes | 2 | N/R | 62 |
| Unusual hearing | No | 15 | Yes | 2 | N/R | 51 |
| Handed | Right | 56 | Left | 10 | Ambidextrous | 3 |

N/R = No Response

Participants were randomly assigned to one of a number of different groups, which determined their treatment as defined in the experiment design.

The first participant group was the *Preliminary* group, which participated in pilot studies. The Preliminary group included ten participants, and their results were encoded as P-xxx-[H | S], where "P" indicates Preliminary, "xxx" ranged from 001 to 010, and "H | S" indicates the VE was presented via a HMD or "S" if the VE was presented via a Computer Projection Screen.

The second participant group was the *Baseline* group, which served as a control group experiencing none of the cues designed to enable the perception of the affordances. The Baseline group included five participants, and their results were encoded as B-xxx-[H | S], where "B" indicates Baseline and "xxx" is a number from 001-005, and "H | S" is as for the Preliminary group. The control group experienced changes in the room configurations (e.g., different passageway widths) but were not provided with any cueing. The results from this group re-establish what is already known about affordances in VEs -- they are not perceived as they are in the real world.

The third participant group was the *Final* group, which experienced the formal treatment as discussed in the experiment design. The Final group included 43 participants, and their results were encoded as Fxxx-[H | S], where "xxx" is a number from 001 to 043, and "H | S" is as for the Preliminary group. This group was divided into two subgroups because of complications with the "thud" cue, which was judged to be unsatisfactory and thus was changed after F020. This was the only change between the F001-020 and F021-043 groups.

The fourth participant group was the *Header* group. The Header group included three participants, and their results were encoded as Hxxx-H, where "xxx" is a number from 001-005. This group was only run with the HMD. Observing the participants' decisions to fly or not led to insights into the perception of this affordance. The original window that participants could fly through had no "top" or header (i.e., the window was not constrained in four directions as was the doorway), the presence of which could have diminished its ability to afford flying. The VE was thus modified to include a "header" on each wall, and an additional participant group was run with this configuration.

The fifth participant group was the *Alternate* group. The Alternate group included five participants, and their results were encoded as Axxx-H, where "xxx" is a number from 001-005. This group was only run with the HMD. Although the order of configuration was randomly selected, to confirm that the particular order of room configurations (see Figure 8) was not incidentally a fortunate one particularly conducive to realizing affordances, an "alternate" group was run with a different randomly selected room configuration.

Five participants began and were unable to complete the experiment. For the most part, they became too ill to continue. One participant played with the apparatus, crashed the environment, and declined to complete the experiment. The participants that did not complete the experiment were encoded as Xxxx-[H | S], where "xxx" is a number from 001-005, and "H | S" is as for the Preliminary group. Upon starting analysis, the results files for participant F039 were found to be corrupted, so F039 was not considered in the analysis. Finally, one participant had a profound loss of hearing, and this result was separately encoded as I001.

## **Apparatus**

All of the experiments utilized the same apparatus. A VE was implemented in a Renderware engine running on PC in Windows 2000. The engine is capable of simulating collision detection, networking, avatars, and some special effects. Graphics models were constructed in 3D Studio Max, and exported in Renderware's format. Visual and audio information were presented in one of two modes: either a Virtual Research V6tm HMD or a Sharp NV2U Computer Projector. The resolution of the HMD was 640 x 480 pixels spread over two eye point displays; the resolution of the projector was 800 x 600 pixels. For both presentation modes, the participants were positioned 8 feet from the projection screen in a nonadjustable height chair at a desk 30" high off the ground with no obstacles within their reach. The participants were asked to line up their chairs on a piece of masking tape marking the center line of the project screen. Users controlled their movements throughout the VE with an optical computer mouse.

Three questionnaires were used in this experiment.

1) Immersive Tendencies Questionnaire: a 34 question survey, with each question answered along a seven point scale, which indicates how likely the respondent is to immerse (or "lose") themselves in an artificial experience (see Witmer & Singer, 1996)

2) Motion History Questionnaire: a 20 question survey, with multiple response formats, that creates a record of the respondent's experience with various kinds of artificial motion and motion sickness (see Kennedy & McCauley, 1984)

3) Simulator Sickness Questionnaire (SSQ): a 27 question survey, with each question answered along a four point scale from "none" to "severe", which creates a measure of the respondent's present physical well-being (see Kennedy Lane, Berbaum, & Lilienthal, 1993).

## Tasks

Participants conducted activities in a VE that required walking through passageways, running to catch an object, and flying. These tasks were incorporated into a game-based theme to maintain participant interest. The tasks involved traversing a series of virtual rooms, which exhibited varying perceptual stimuli (i.e., each room was configured per the experimental design discussed below). In each room, the participant was asked to approach an orientation post in order to orient within the room and then exit the room as appropriate for the experiment configured in it. The orientation post was located fifteen meters from and centered on the exit wall in each room. Successful orientation by the participant triggered the post to sink into the ground during which the participant's position was frozen. After sinking, the post was positioned to the next room to assist in orienting the participant during the next task.

For the passability task, participants were instructed that if the room had a single exit, then they should first trigger the orientation post and then exit the room's passageway in the most comfortable way, i.e., rotate if that made it easier to exit the room. The VE measured the participant's actual behavior in order to assess passability (i.e., rotation angle).

For the catchability task, participants were instructed that if a room had two passageway exits and a cannon on the floor, the participant should first trigger the orientation post and then observe a virtual ball shot from the cannon and judge whether the ball was catchable or not. Participants were told that movement might improve their judgment. The virtual cannon was located on the far wall across from the entrance in direct line with the orientation post. Once the ball was shot, the participant was to judge whether they could have caught the ball in the air from their location when the ball was shot. The balls were shot with velocities that led to their impact on the floor within about two (uncatchable) to three (catchable) seconds. Upon impact, the balls bounced off the floor. The ball was shot as either uncatchable (landing more than > 1.2 times the participant's range) or catchable (landing <=1.2 times the participants range) as defined by the experimental condition; the values being chosen for consistency with Oudejans et al. (1987). Catchable balls had greater initial speeds and achieved a greater height than uncatchable balls. Participants were instructed to record their catchability judgment by exiting out of one of the two passageways leaving the room, either the left passageway (also marked by a green block) if the ball was catchable in the air, or the right passageway (also marked by a red block) if it was not. The VE measured the participant's actual behavior in regards to catchability (i.e., which door they exited).

For the flyability task, participants were instructed that if the room had a passageway and a window, then they should first trigger the orientation post and then exit either room's passageway or window in the most comfortable way (i.e., fly if that is easier). The VE measured the participant's actual behavior in regards to flyability by recording the altitude above floor level (or 'ground") at which they exited the room. A more detailed explanation of the tasks is in the protocol contained in Appendix A.

## Virtual Environment

The following discussion explains the representation in the VE experienced by the participants. In order to address the validity issues discussed, and to make the gathering of the experimental data as efficient as possible, the experimental program occurred in a single integrated virtual experience.

The virtual world modeled was similar to the interior of the University of Central Florida Engineering II building with regard to walls. The ceiling was modeled as a cloudy sky, so that participants could fly without concern for colliding with the ceiling. The result was an outdoor maze-like structure. Each participant's original position in the virtual world was within a large room used to orient them to the controls. Figure 7 illustrates the initial position of each participant within the virtual environment.

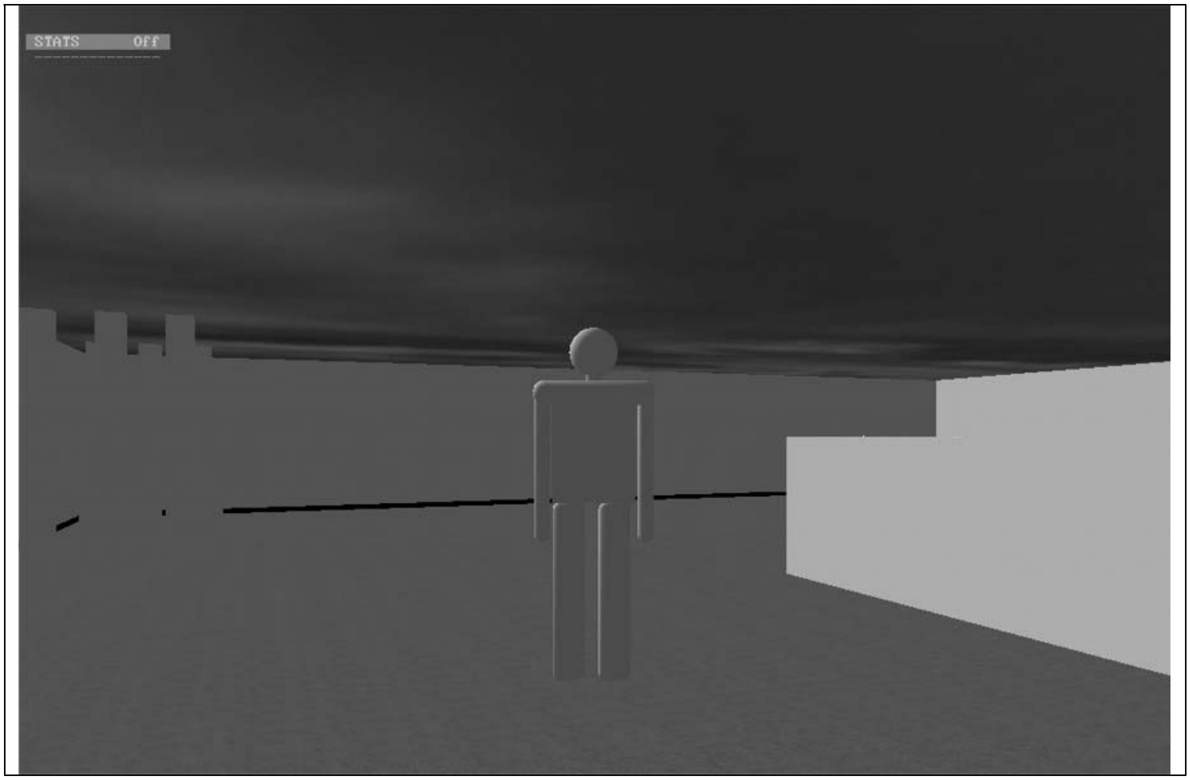


Figure 7: Participants' initial position within the virtual environment.

The qualities of the cues in this environment are of concern as the sophistication of the various visual and audio cues may be an unblocked source confounded with the dependent variables. Surdick, Davis, King, and Hodges (1997) studied the impact of seven different visual cues (brightness, relative size, relative height, linear perspective, foreshortening, texture gradient, and stereopsis) on the perception of distance in virtual environments. They found that foreshortening, linear perspective, and texture gradient were sufficient for perception of the distance of geometric objects. The VE used as the experimental apparatus therefore included high quality representations of these so-called ground intercept cues and comparatively low quality representations of the other cues. Foreshortening and linear perspective were fully enabled in the virtual environment. Strong texture differentials between the walls and floors were employed (i.e., walls appeared as "flat paint" whereas floors were a patterned carpet). Brightness was accounted for as a single directional light source, which provided minimal contrast. The size and height of objects in the VE were correct in relation to one another but many small details, such as light switches, were omitted. The VE was not stereoscopic; the same image was presented to each eye within the HMD.

There were 26 separate rooms in the VE, including the orientation room, 24 task rooms in which the experimental conditions were presented, and a completion room. The orientation and the completion rooms were represented as 25 by 25 meters. Each of the task rooms were represented as five meters wide by 20 meters long. The rooms were arranged in a serpentine fashion to prevent the participant from seeing the configuration of the next room through the exits to the current room. The participant's initial position was in the orientation room in which the participant was directed through a series of familiarization tasks. When ready, the participant exited the orientation room and progressed through the task rooms. To assist the participant in continuing correct progress through the rooms, an orientation cue (represented as a triangular post) was presented at the entrance to every room. When participants entered a room correctly positioned, the cue sunk into the ground, and emerged in the next room. After progressing through all of the task rooms, the participant emerged into a large completion room and the VE was terminated. Figure 8 shows the layout of the rooms in the VE, from the orientation room, through the 24 task rooms, to the completion room. Figures 9 through 11 are examples of passability, catchability, and flyability rooms, in turn.

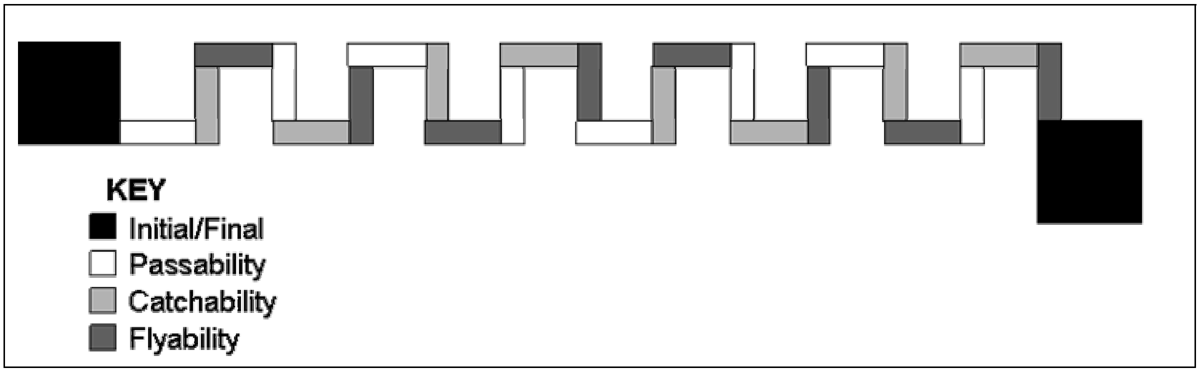


Figure 8: Layout of the virtual environment.

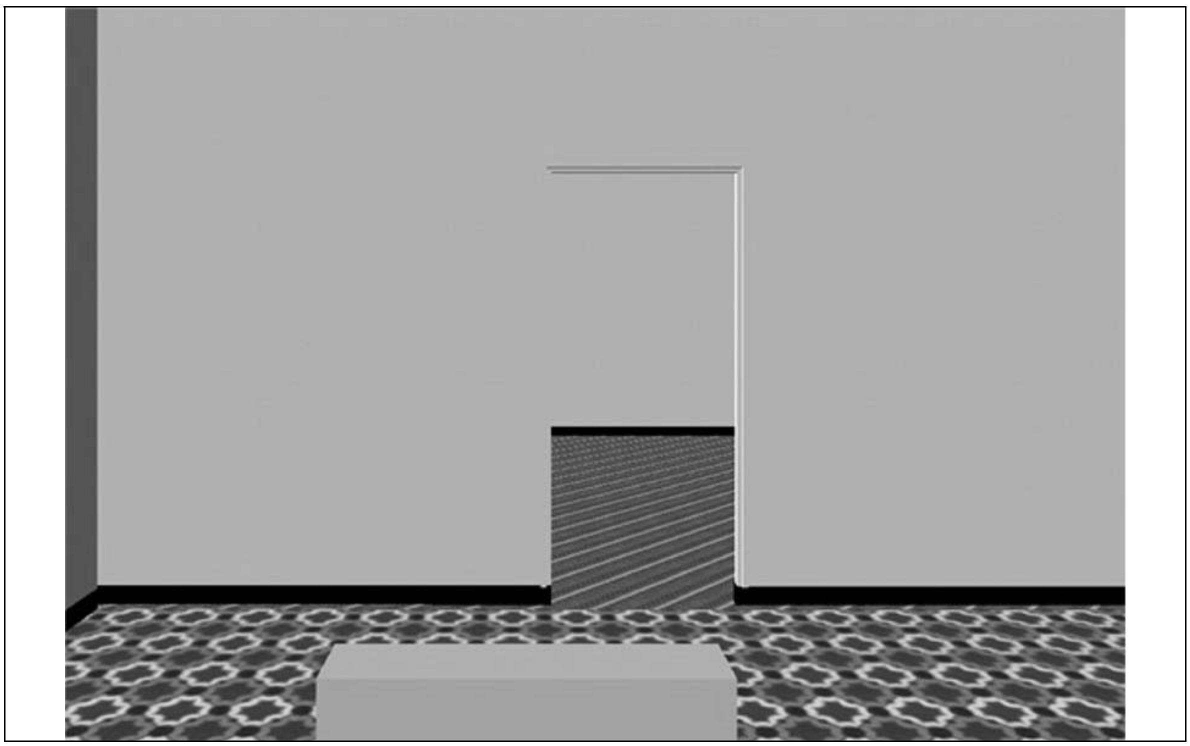

Figure 9: Example of a passability room.

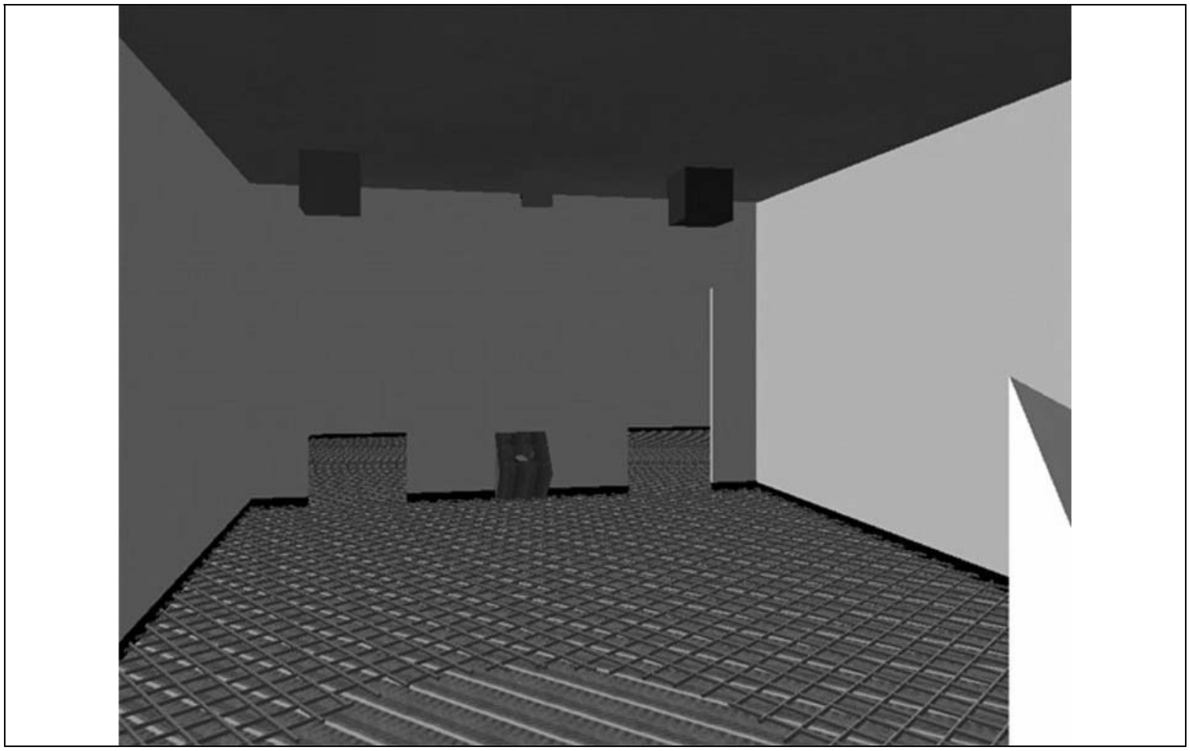

Figure 10: Example of a catchability room.

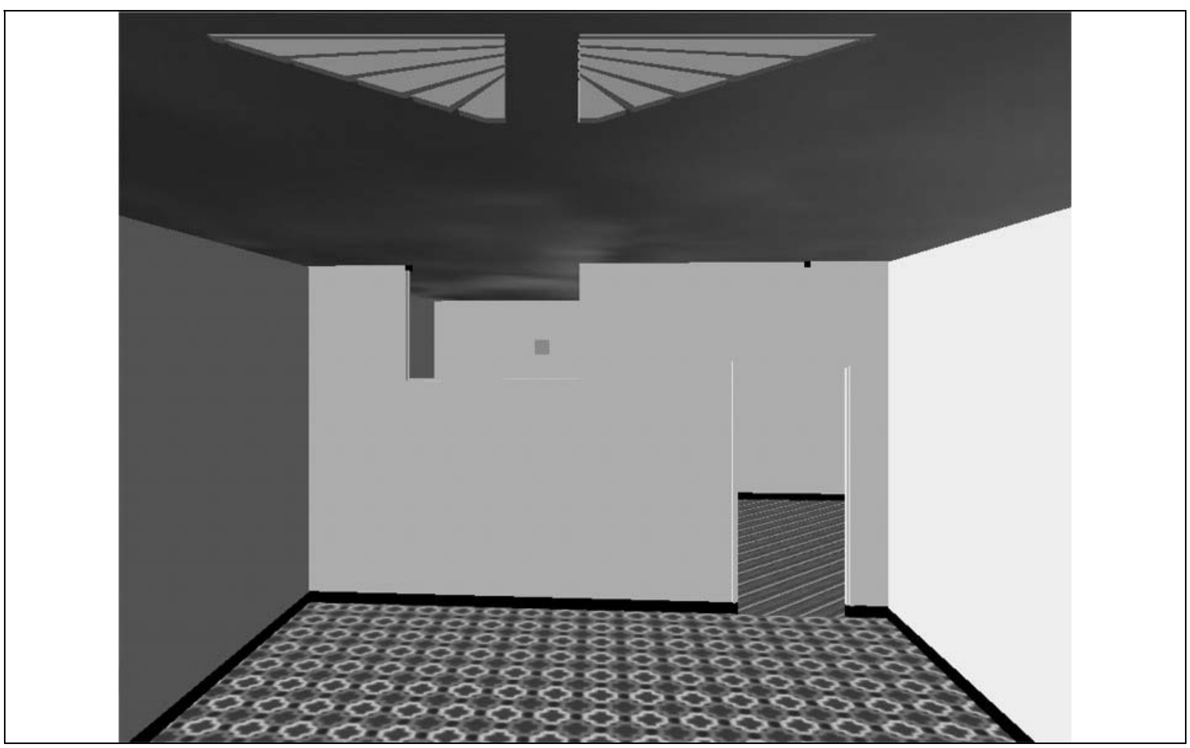

Figure 11: Example of a flyability room.

## Procedure

Appendix A contains the protocol for the experiment as summarized in the following discussion. The protocol was defined by a script for the experimenter to use in briefing each participant and exercising the apparatus. The general procedure was as follows:

1) Informed Consent
2) Pre-questionnaires (demographics, etc.)
3) Briefing on environment
4) Entry into environment
5) For each task:
   - Briefing on objective
   - Observe behavior
   - Performance measurement
   - Post-questionnaires
   - Results recorded

First, all participants were briefed and asked to make an informed consent to the experiment. No participants declined to participate at this point. After indicating their informed consent, participants completed a demographics form, an Immersive Tendencies Questionnaire (Witmer & Singer, 1996), and Motion History Questionnaire (Kennedy & McCauley, 1984). Prior to exposure to the VE, each participant completed the Simulator Sickness Questionnaire (SSQ) to baseline their well-being prior to exposure (Kennedy et al., 1993). In order to proceed with the experiment, each participant's pre-SSQ score had to fall below 7.48, which qualified the participant to be in good health for the experiment.

Each participant was randomly assigned to one of the treatment conditions as discussed in the section following. The experimenter briefed each participant on the use of controls for movement, rotation, and flight in the VE as defined in Appendix A. The experimenter encouraged each participant to become comfortable with these controls in the orientation room by maneuvering around obstacles placed in the room. The experimenter instructed each participant to exit the orientation room when comfortable with the controls through the only passageway in the orientation room.

During exposure, participants maintained a seated position while wearing an HMD and traversing through the VE completing the tasks described above. The exposure time for each treatment was approximately 30 minutes. Immediately following each exposure period, post-SSQ measures were obtained. If the participant's score exceeded the threshold value of 7.48, the experimenter terminated the experiment. If the experimenter terminated the experiment, the experimenter encouraged the participant to follow a recovery protocol until their SSQ score fell below the threshold.

## **Experimental Design**

The experimental design consisted of a series of experiments, each of which tested the hypotheses in a range of conditions. The experimental space was required to address six hypotheses and the dependent variables implied by those hypotheses. The related independent variables that affected the dependent variables were numerous. The experimental design therefore adopted the sequential experimentation approach recommended by Han, Williges, and Williges (1997). The experimental design adopted three main parts of the sequential experimentation approach:

1) Screening Studies: The experimental program conducted pilot studies to screen for the appropriate levels for each factor based on qualitative and quantitative information collected. Preliminary experimental runs provided qualitative and quantitative information to assess the level of the cues presented, which were adjusted for the final experimental runs.

2) Division of the independent variable into subsets: The experimental program divided independent variables into subsets, one subset for each of the three affordances under consideration. The result of this was to reduce the experimental space from twenty-four independent variables (requiring 128 run configurations for a resolution IV design) to three subsets of four independent variables (requiring 24 run configurations for a resolution IV design).

3) Sufficient resolution: The experimental design left main effects and two way interactions un-confounded.

The independent variables for each subset may be further divided into two classes: those providing evoking circumstances and those providing substitutionary cues for physical characteristics which may enable the realization of a given affordance. The evoking circumstances test the properties of objects within the environment under levels that should lead to the realization of an affordance and levels which should not. The following discussion explains the evoking circumstances for each affordance (passability, catchability, and flyability), and the form of the substitutionary cues for physical characteristics and object properties considered.

## Passability Experiment

The theoretical discussion developed a hypothesis that a VE could enable the realization of the passability affordance by providing cues as to the participant's body characteristics substituting for missing, impoverished, and conflicted kinesthetic and vestibular sensory stimuli. A successful substitution scheme enabling the realization of passability should result in the average VE user matching the 1:1.3 shoulder width to passage width ratio for comfortable passage found in Warren and Whang's (1987) study. Stappers (1999) found that this affordance is not realized in VEs as it is in realty. It was not known in advance what substitution stimuli would be most effective, thus a hypothesis secondary to the first, was developed that appropriate cues for body stature could be found. Table 9 shows the physical characteristic cues that the passability experiment investigated. In the experimental conditions in which these cues were active, participants saw these cues during their entire time in the task room.

Table 9: Substitutionary cues for physical characteristics possibly enabling passability.

| **Passability cues** | **Form of the Cue** | **Cue Behavior** | **Motivation** |
|---|---|---|---|
| Bar | • Horizontal rectangular block (see Figure 9)<br>• Width defined by virtual shoulder width<br>• Superimposed on an egocentric view (across bottom) | • Match position and heading to virtual body's when mouse moved<br>• Rotate around vertical axis when virtual body rotated by depressing left mouse button | • Minimal stimuli about shoulder width |
| Form | • Simplified head, neck, and shoulders<br>• Width defined by virtual shoulder width<br>• Superimposed on an egocentric view (across bottom) | • Match position and heading to virtual body's when mouse moved<br>• Rotate around vertical axis when virtual body rotated by depressing left mouse button | • More than minimal stimuli about shoulder width |
| Peripheral | • Gap in cross-hatched mesh in plane parallel with the walls<br>• Gap width defined by virtual shoulder width<br>• Superimposed on a egocentric view (top to bottom) | • Match position and heading to virtual body's when mouse moved | • Maximum stimuli about shoulder width |

The passability experiment required participants to choose whether or not to rotate their virtual body so as to facilitate their exit. The task rooms for the passability experiment had a single exit, a passageway of varying widths from room to room. Passability is evoked in circumstances where an observer perceives the passageway as being narrow, and is not evoked when the observer perceives the passageway to be wide. The passability experiment therefore includes an independent variable for the actual width of the passageway as an evoking circumstance. If the substitutionary cues for physical characteristics possibly enabling passability are effective, then most participants should rotate when presented with narrow passageways, and few should when presented with wide passageways. Based on the data found in Warren and Whang (1987) and Stappers (1999), the experimental design assigned 80% as the predicted value for 'most' rotating, and 20% as the predicted value for 'few' rotating.

Table 10 shows the independent variables for the passability experiment, which included the presence or absence of each cue, in addition to passageway width. The levels considered for the evoking circumstance of passability, namely passageway width, bracket the 1:1.3 ratio (i.e., levels of 1 and 1.5 times the shoulder width) at which passability has been shown to be afforded, which should result in a measurable effect. The dependent variable measured in the VE was degree of body rotation, which indicated whether passability had been realized or not.

Table 10: Independent variables for the passability experiment.

| **Variable** | **Level (-)** | **Level (+)** |
|---|---|---|
| Bar cue | Absent | Present |
| Form cue | Absent | Present |
| Peripheral cue | Absent | Present |
| Passage width | 1.0 x user's shoulders | 1.5 x user's shoulders |

## Catchability Experiment

The theoretical discussion developed a hypothesis that a VE could enable the realization of the catchability affordance by providing cues as to the participant's action capabilities. A successful substitution scheme enabling the realization of catchability should result in the average VE user matching the catchability judgments values found in Oudejans et al. (1996), specifically the 1:1.2 ratio of actually catchable balls to those perceived catchable. This cue would provide information substituting for missing, impoverished, and conflicted kinesthetic and vestibular sensory stimuli. It was not known in advance what substitution stimuli would be most effective, thus a hypothesis secondary to the first was developed that appropriate cues for self-acceleration and range could be found. For example, it was possible that either visual or auditory stimuli would be sufficient, so the experiment had to be able to analyze the separate contributing effects of each stimulus. Table 11 shows the physical characteristic cues of self-acceleration and range cues that the catchability experiment investigated. In the experimental conditions in which these cues were active, participants heard or saw these cues upon entering the room and approaching the orientation post, as well as if movements were made after the cannon ball was shot.

Table 11: Substitutionary cues for physical characteristics possibly enabling catchability.

| Catchability cue | Form of the Cue | Cue Behavior | Motivation |
|---|---|---|---|
| Stick | • Vertical rectangular block<br>• Height defined by virtual shoulder width<br>• Superimposed on an egocentric view (centered, low) | • Match position and heading to virtual body's changes when mouse moved<br>• Rotate around horizontal axis away from the user as speed increased | • Minimal visual stimuli about self-acceleration and velocity |
| Thud | • Auditory "beeps"<br>• Separation distance between beeps indicated speed | • Separation distance between beeps inversely and exponentially related to speed | • Audio stimuli about self-acceleration and velocity |
| Periphery | • Cross-hatched mesh plane parallel with the floor (see Figure 10)<br>• Circular gap width defined by reach range at current location<br>• Superimposed on a egocentric view (slightly off the floor) | • Match position and heading to virtual body's changes when mouse moved | • Maximum visual Stimuli about self-acceleration and velocity |

The catchability experiment required participants to judge whether or not a ball was catchable, that is, whether or not they could maneuver so as to intercept the ball in the air. The task rooms for the catchability experiment contained two exits (a left and right door), and a cannon. After the participant successfully approached the orientation post, a ball was fired from the cannon. Catchability is evoked in circumstances where an observer perceives an object (e.g., a ball) to be within their reach range, and is not evoked when the observer perceives the object to be outside of their reach range. The catchability experiment therefore includes an independent variable for the shot range of the ball as an evoking circumstance. If the substitutionary cues for physical characteristics enabling catchability are effective, then most participants should judge the ball catchable when presented with a ball shot in range, and few should when presented with a ball shot out of range. Based on the data found in Oudejans et al. (1996), the experimental design assigned 80% as the predicted value for 'most' correctly judging catchability, and 20% as the predicted value for 'few' correctly judging catchability.

Table 12 shows the independent variables for the catchability experiment, which included the presence or absence of each cue considered, as well as the shot range (i.e., uncatchable versus catchable). The levels considered for the evoking circumstance of catchability, namely shot range, bracket the 1:1.2 ratio at which catchability has been shown to be afforded, which should result in a measurable effect. Specifically, balls shot in range fall within reach of the participant's range (<=1.2) from the time of shot, and balls shot out of range fall outside of a circle whose radius is 1.5 times the range of the participant from the time of the shot. The dependent variable was body position relative to the exit passageway location in meters, which indicated whether catchability had been realized or not. Exiting the left passageway indicated the participant believed the ball to be catchable, whereas exiting the right meant that the participant judged it not to be catchable.

Table 12: Independent variables for the catchability experiment.

| **Variable** | **Level (-)** | **Level (+)** |
|---|---|---|
| Stick cue | Absent | Present |
| Thud cue | Absent | Present |
| Peripheral cue | Absent | Present |
| Shot range | Out of range | In range |

## Flyability Experiment

The theoretical discussion developed a hypothesis that a VE could enable the realization of the flyability affordance by providing cues as to a user's body size, substituting for missing, impoverished, and conflicted kinesthetic and vestibular sensory stimuli. A successful substitution scheme enabling the realization of flyability should result in the average VE user choosing to fly. It was not known in advance what substitution stimuli would be most effective, thus a hypothesis secondary to the first was developed that appropriate cues for body size could be found. Therefore, the flyability experiment presented a range of substitution stimuli that might be appropriate for body size. Table 13 shows the physical characteristic cues that the flyability experiment investigated. In the experimental conditions in which these cues were active, participants saw these cues during their entire time in the task room.

Table 13: Substitutionary cues for physical characteristics possibly enabling flyability.

| Flyability cue | Form of the Cue | Cue Behavior | Motivation |
|---|---|---|---|
| Wings | • Stylized wing (see Figure 11)<br>• Gap width defined by virtual shoulder width<br>• Superimposed on an egocentric view (across top) | • Match position and heading to virtual body's changes when mouse moved<br>• Rotate around vertical axis when virtual body rotated by depressing left mouse button | • Minimum stimuli about body width and height |
| Periphery | • Gap in cross-hatched mesh in plane parallel with the walls<br>• Gap width defined by virtual shoulder width and body height<br>• Superimposed on a egocentric view (top to bottom) | • Match position and heading to virtual body's changes when mouse moved | • Maximum stimuli about shoulder width and body height |

The flyability experiment required users to choose between two forms of locomotion, namely flying or walking. The task rooms for the flyability experiment included two exits: one a ground level doorway to the side of the straight-ahead path, and one a window directly in front of the user. Flyability is not an affordance present in reality; therefore its evoking circumstances are unknown. The experimental design includes two independent variables that may be evoking circumstances for flyability: window height and window width. As in passability and catchability, the supposition is that flyability will be evoked when observers perceive that flying is possible and easier than other choices. The supposition is that participants would be more likely to fly over low, wide windows, and less likely to flow over high, narrow windows. If the substitutionary cues for physical characteristics possibly enabling flyability are effective, then most participants should chose to fly when presented with low, wide windows, few should choose to fly when presented with high, narrow windows, and some should choose to fly in the intermediate conditions (high-wide or low-narrow). To maintain consistency with the other affordances, the experimental design assigned 80% as the predicted value for 'most' flying and 20% as the predicted value for 'few' flying; while adding a third condition of 50% for 'some' flying.

Table 14 shows the independent variables for the flyability experiment, which included the flyability cues, as well as the height of the window off the ground. There could have been effects that confound the realization of flyability, such as the size of the aperture (window) to fly through, so the flyability experiment included window width as a blocking variable. The lower values in Table 14 match experiences users have in the real world for climbing through a window using a ladder (Warren, 1984). The higher values were chosen to create a likelihood of seeing an effect, namely that users would choose to fly. Finally, the dependent variable was altitude above the floor as measured in meters, which indicated whether flyability had been realized, or not.

Table 14: Independent variables for the flyability experiment.

| **Variable** | **Level (-)** | **Level (+)** |
|---|---|---|
| Wings Cue | Present | Absent |
| Peripheral Cue | Present | Absent |
| Height of window | 1.0 meters | 2 meters |
| Width of Window | 1.5 meters | 2 meters |

The passability, catchability, and flyability experiments presented two levels of five factors, resulting in $2^4$ (i.e., 16) different cases. Since the purpose of these experiments was to discover main effects, and resources are a constraint on any experiment, these experiments were conducted as a $2_{IV}^{4-1}$ fractional factorial design, as illustrated in Table 15. This is a resolution IV design, in which main effects were confounded with three way interactions, as recommended in Han, Williges, and Williges (1997).

Table 15: Standard $2_{IV}^{4-1}$ fractional factorial design.

| **Case** | **A** | **B** | **C** | **D=ABC** |
|---|---|---|---|---|
| 1 | - | - | - | - |
| 2 | + | - | - | + |
| 3 | - | + | - | + |
| 4 | + | + | - | - |
| 5 | - | - | + | + |
| 6 | + | - | + | - |
| 7 | - | + | + | - |
| 8 | + | + | + | + |

Table 16 shows the overall experimental design in standard order for the factors for each affordance. The factors are the various substitutionary cues and evoking circumstances that should lead to the perception of the affordance; the combination of which define a configuration. The design required eight configurations for each affordance (as opposed to sixteen configurations in the full factorial design). There were three affordances considered, so there was a total of 3x8 or 24 configurations to run. The configurations were presented to the participant in a series of virtual "rooms," with one configuration per room. Per standard experimental procedure, the configurations were presented in a random order, with a passability room always preceding a catchability room, which in turn always preceding a flyability room. More specifically, in order to block undesirable learning effects, the rooms were configured in random order, except that the selection ensured a rotation between passability, catchability, and flyability configurations. For example, a catchability or flyability room always succeeded a passability room, never another passability room. Therefore, the order within each class of rooms was randomly selected. An arbitrary 24 different random selections was made to select the presentation order of the experimental conditions. Each participant constitutes a replication of the 24 conditions, except that participants in the Baseline group experienced only the evoking circumstances and those in the alternative group experienced the rooms in a different order.

Table 16: Overall experimental design.

| **Treatment Condition** | **Affordance Cue** | | | | **Presentation Order** |
|---|---|---|---|---|---|
| **Passability** | **Bar Cue** | **Form Cue** | **Peripheral Cue** | **Passage Width** | |
| 1 | - | - | - | - (narrow) | 7 |
| 2 | + | - | - | + (wide) | 1 |
| 3 | - | + | - | + | 10 |
| 4 | + | + | - | - | 19 |
| 5 | - | - | + | + | 13 |
| 6 | + | - | + | - | 22 |
| 7 | - | + | + | - | 16 |
| 8 | + | + | + | + | 4 |
| **Catchability** | **Stick Cue** | **Thud Cue** | **Peripheral Cue** | **Shot Range** | |
| 9 | - | - | - | - (catchable) | 5 |
| 10 | + | - | - | + (not) | 20 |
| 11 | - | + | - | + | 14 |
| 12 | + | + | - | - | 11 |
| 13 | - | - | + | + | 17 |
| 14 | + | - | + | - | 23 |
| 15 | - | + | + | - | 2 |
| 16 | + | + | + | + | 8 |
| **Flyability** | **Wings Cue** | **Peripheral Cue** | **Height of Window** | **Width of Window** | |
| 17 | - | - | - (short) | - (narrow) | 9 |
| 18 | + | - | - | + (wide) | 6 |
| 19 | - | + | - | + | 21 |
| 20 | + | + | - | - | 15 |
| 21 | - | - | + (tall) | + | 18 |
| 22 | + | - | + | - | 3 |
| 23 | - | + | + | - | 24 |
| 24 | + | + | + | + | 12 |

+ = cue present; - = cue absent (except were noted otherwise)

An additional issue is the possibility that the presentation media used might effect the perception of an affordance. Therefore, the design included presentation media as an additional “super factor” with two levels: HMD and computer projector on a screen. This was implemented by repeating the configuration in Table 16 for each participant, alternating whether the HMD or the projector was first used.

In the complete experimental design each participant was exposed to all of the required configurations twice, once with the HMD and once with the Screen, thereby supporting analysis of effects within and between subjects for all of the factors.

## Experimental Validity

Weimer (1995) identifies two main ways in which the validity of an experimental program can be evaluated: internal and external validity.

### Internal Validity

Internal validity is the degree to which one can draw the conclusion that manipulation of the independent variables, and only that manipulation, has caused the observed change in the dependent variables. Internal validity, establishes that differences observed in the dependent variables are caused by changes in the independent variables, rather than simply correlated to those changes. There are a number of threats to internal validity, such as low statistical power, which means that true differences are not noted, and random heterogeneity, which means that differences noted are not true. These threats can be addressed by increasing the number of participants per group, and considering group differences (Gray & Salzman, 1998). For the present research's experimental program, initial trials were used to predict the population variance, which in turn was used to select the number of samples required to resolve statistical tests to the standard 95% confidence level (Box, Hunter & Hunter, 1974). To address group differences, each participant was required to complete a form capturing their experience with VEs specifically and with HCIs in general.

Misuse of observation instrumentation is another threat to internal validity (Weimer, 1995). In this experimental program, the observation instrumentation was a time marked record of the results of the user's control inputs in terms of their position in the virtual environment.

Another threat to internal validity is a bias in the participant sample (Gray & Salzman, 1998). Participants were drawn from the Boeing Company's Huntsville work force. This group is roughly representative of the general population in many measures, but likely has more formal education than the populace at large. One strength of this sample group is that its age distribution is greater than a typical college environment.

A final threat to internal validity is unblocked variance in the experiment setting (Gray & Salzman, 1998). For the present research's experimental program, the setting was a standard laboratory and data collection occurred during normal business hours.

### External Validity

External validity refers to the legitimacy of generalizing the results of the experiment to the population at large (Weimer, 1995). It is very difficult to get a true measure of the research's external validity. Threats to external validity include:

1) interaction between (pre)testing and the independent variables,
2) interaction between selection and the independent variables,
3) reactive effects of setting, and
4) multiple treatment interference.

Attempts were made to control these threats in the experimental design. For example, all participants received the same training period to learn the VE controls. The experimental setting was designed to eliminate reactive effects, including placing the user in immersive and non-immersive settings. Finally, the experimental design blocks the effects of multiple treatments.

# CHAPTER 4: RESULTS

The participant's responses to the Immersive Tendencies Questionnaire (Witmer & Singer, 1996), the Motion History Questionnaire (Kennedy & McCauley, 1984), and Simulator Sickness Questionnaire (Kennedy et al., 1993)  resulting from the various surveys were analyzed by participant group, and found to demonstrate that there were no statistically significant differences between the groups.  See Appendix B for this analysis.

## Pilot Study

A pilot study was run to confirm that the experimental apparatus and design functioned appropriately.  Table 17 shows issues discovered in preliminary runs and corrective actions taken. The results from the pilot study were thus used to revise the experimental apparatus and design, which were then used for the formal study.

Table 17: Issues discovered in the pilot study.

| Issues | Corrective Actions |
|---|---|
| At the maximum altitude, users cannot see the window that they are trying to fly thru; effect is to increase difficulty of flying | Reduce maximum height such that users can see the window they fly through |
| "Negative Z" direction rooms have green and red backwards | Correct mislabeled catchability exits |
| Users remarked on cues they noticed, while not seeming to notice some cues this could be an interesting result | Add survey concerning "what cues did you notice?" |
| Current wings are wider than windows, which create a passability mis-affordance | Reduce wings width to between wide and narrow window width |
| Current bell sound for foot fall "thud" is linear, and the response does not change enough to help | Make foot thud an exponential curve |
| Various typographical errors and incorrect story line in briefing | Correct briefing |
| Short ball does not rise as high as long ball, making it easy to tell by eye if it's catchable | Make short ball's height match long ball's |
| Current columns are as high as the walls making the distance between them appear much smaller, which impedes training of passability | Reduce training columns height to match doorways |
| One passability room did not match experimental design | Correct passability encoding |

## Formal Study

The VE recorded each participant's behavior in the VE in a text formatted raw data file as show in Appendix C. The raw data consisted of room number, x position, y position, z position, rotation angle and speed for each video frame created. The VE ran at approximately 30 hertz, meaning that 30 frames were created every second of clock time. Neglecting aborted runs, the smallest resulting data file was 0.376 megabytes and the largest was 5.152 megabytes (P003-H) for a total of 238 megabytes of original data. The data collected consisted of more than 600,000 observations.

## Analysis of Single Runs

The first analysis focused on analyzing single runs in terms of the raw data as related in the following discussion. The purpose of this analysis was to confirm that the VE was performing as expected; specifically that user behavior could be measured with raw data being collected (i.e., ensure data wasn't too noisy, needing transformation). Several single runs were subjected to this analysis. For the sake of space, the following discussion is constructed on a few random samples from the single runs.

Figure 12 plots a randomly selected participant's speed as a function of time in the virtual environment. It shows the participant accelerating and decelerating as they interact with the environment. Negative speed indicates that the participant was going backwards (i.e., this is actually velocity). Speed was not a dependent variable for any of the hypotheses, but provides confirmation of the VE's performance.

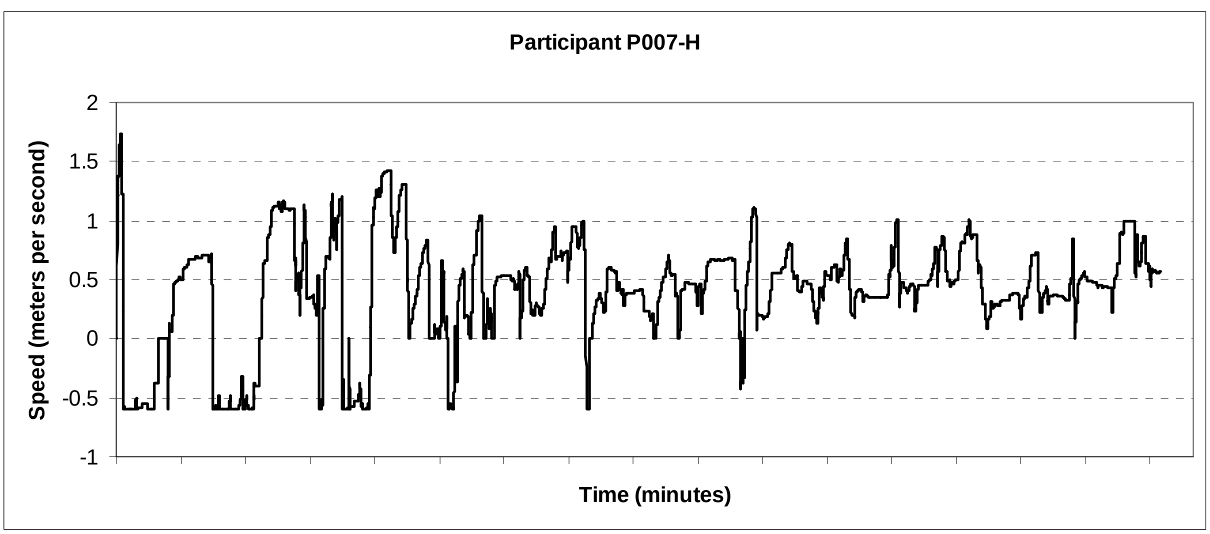


Figure 12: Typical participant speed (meters per second).

Figure 13 plots a randomly selected participant's body rotation as a function of time in the environment. Body rotation was the dependent variable for the passability experiment. This indicates that this participant was not typically or randomly rotating, but was rotating at discrete measurable times.

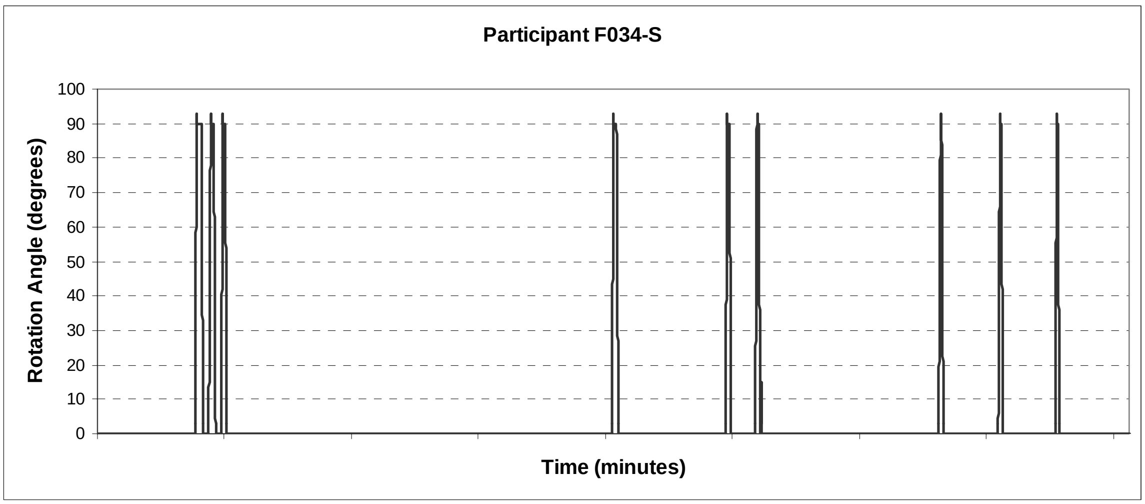


Figure 13: Typical participant rotation (degrees to the left)

Figure 14 plots a randomly selected participant's position on the horizontal plane in the virtual environment. In Renderware, the horizontal plane is actually the X-Z plane, with positive Z down and positive X to the right. Position was the dependent variable for the catchability experiment. Position indicates if the participant exited out of the left (indicating that the ball could have been caught) or the right (indicating that it could not have been caught) passageway.

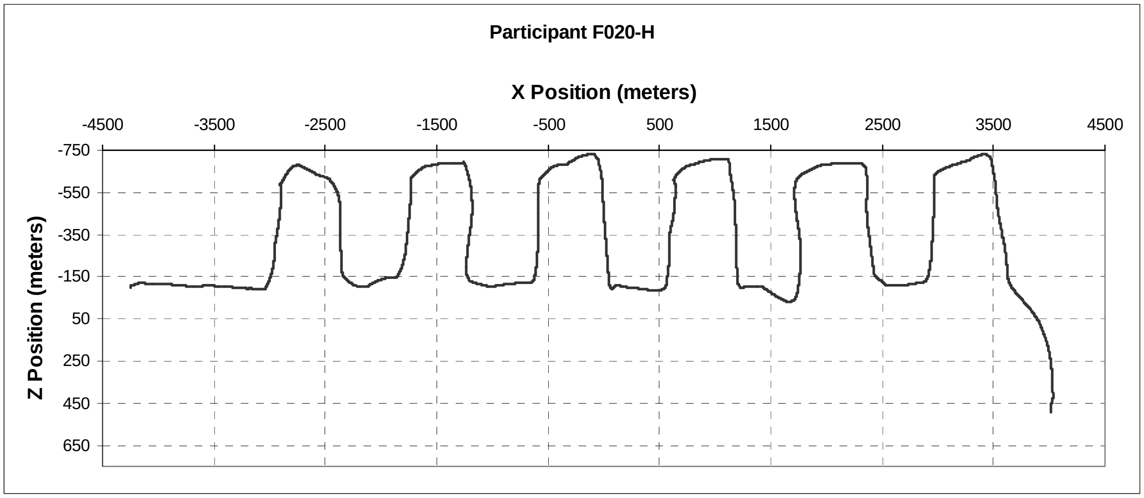


Figure 14: Typical participant position on the horizontal plane.

Figure 15 plots a randomly selected participant's altitude as a function of time in the virtual environment. In Renderware, altitude is actually position along the Y axis and an altitude of 60 is ground level. Altitude was the dependent variable for the flyability experiment. As was the case for body rotation, Figure 19 indicates that this participant was not typically or randomly flying, but was flying at discrete measurable times. Taken together, this preliminary analysis indicated that it would be feasible to test the hypotheses with the data collected. However, this analysis indicated that the volume of data collected in all the runs was too large to directly analyze as a whole. Data reduction was thus necessary before conducting the across runs analysis. The data reduction is discussed further in the next section.

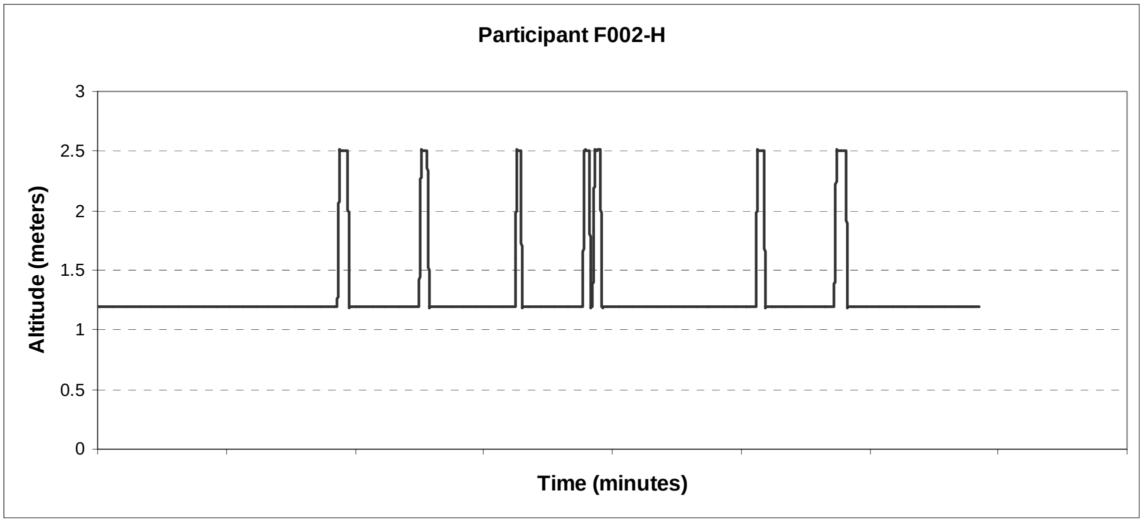


Figure 15: Typical participant's altitude at eye point (meters).

## Data Reduction

The second analysis of measured behavior focused on testing the study hypotheses concerning whether or not participants perceived a given affordance.

Data reduction focused on condensing the raw data into those epochs that could be used to test the hypotheses. Fortunately, the nature of the behaviors to be measured meant that only transitions between rooms were of particular interest. For example, in regards to passability, the dependent variable of body rotation would be expected to be most informative when transitioning from room *i* to room *i+1* because this is when the participant would perceive that rotating would ease the transition. Figure 16 illustrates this point by plotting the transition measured in F020-H's transition from Room 7 to 8 (a passability room). The participant clearly began and completed rotation well in advance of exiting the room, maintained the rotation through the exit, and then rapidly released the rotation after the exit. Likewise, the dependent variable of position would be expected to be most informative for catchability because this is how the participant indicated if the ball was judged catchable. The participant's judgment as to the catchability of a ball is indicated by selection of one of two doors on the wall transitioning from the catchability room to the next room. Finally, in regards to flyability, the dependent variable of altitude would also be expected to be most informative when transitioning between rooms because this is when the participant would perceive that flying would ease the transition. The implication of this realization is that the raw data could be substantially reduced before analysis, perhaps to the single frame indicating room transition.

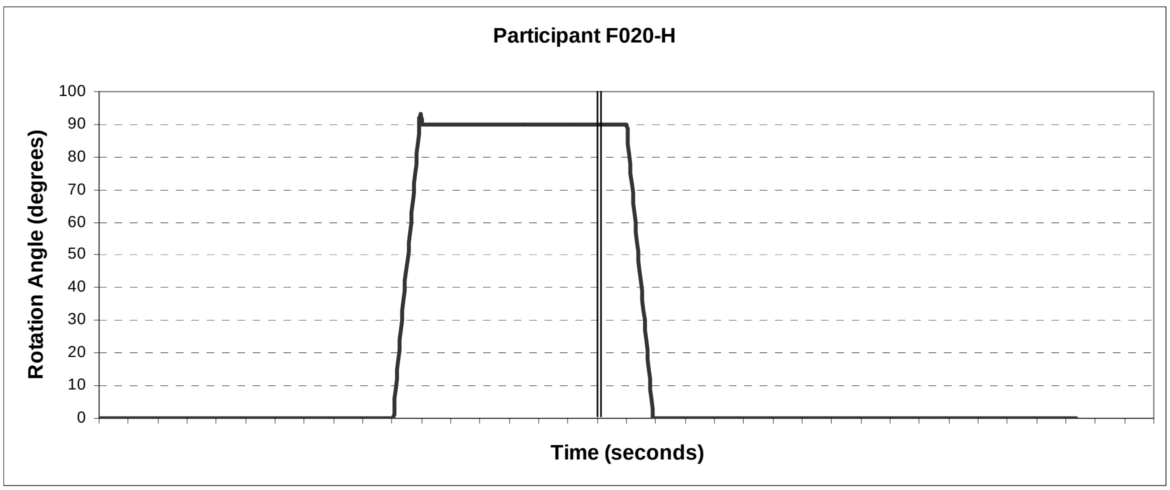


Figure 16: Typical room transition event.

Of course participant's can make mistakes. First, they may execute the expected behavior too early or too late. In the case of passability, this would amount to rotating and releasing *before* exiting or rotating *after* exiting). As the passageways are always wider that the user, there is almost no penalty for this mistake. The exception is alignment error, which occurs when the participant is so misaligned with a passageway as to collide with the wall instead of passing through the passageway. Rotation makes the virtual body narrower and therefore able to slip through passageways with more alignment error than if not rotated. Flyability may generate an analogous behavioral mistake to passability. In the case of catchability, the participant may exit the wrong passageway, for example exiting the *right* passage when the participant judged the ball *catchable*. A second kind of mistake is a control selection error. As explained in the protocol defined in Appendix A, participants controlled body rotation and altitude by depressing mouse buttons. It is possible that participants might have confused the two control buttons, flying when rotating was intended or visa versus. This error could affect the results only in passability and flyability rooms -- catchability rooms do not require special control inputs. Finally, the participants could make a third kind error, a control input error. This would result from a participant selecting a mouse button when no control input was intended. Again, this error could affect the results only in passability and flyability rooms as catchability did not require special control inputs.

Based on the foregoing discussion, the raw data were reduced through a constructed computer program to 12.5 megabytes, a 20:1 reduction. The program extracted several frames of data around each room's transition, and constructed a file capturing the results for all users for each room. Appendix C presents the reduced data set for each task room, and the behavior conclusion for the affordance being considered in that task room. The reduced results were inspected by hand for the errors discussed, which revealed several occurrences. The major error observed was small rotation angles, therefore the analysis adopted the rule that rotation angle had to exceed 15 degrees to be considered an intentional rotation. The rate of occurrences of the other errors was considered too small to justify adoption of additional interpretation rules. Table 18 summarizes the tests for the perception of the affordances that resulted at this stage of the analysis.

Table 18: Tests for perception of each affordance.

| Affordance | Indicating Behavior | Test for Behavior |
|---|---|---|
| Passability | Body rotation | Rotation angle greater than 15 degrees upon exiting |
| Catchability | Position (as compared to room center) | Exiting the room's left door |
| Flyability | Flight | Altitude greater than ground |

## Analysis Across Runs

Comparison of participants' perception of each affordance in the VE to the perception of the affordance typically found under similar circumstances in the real world (as defined by previous studies, see Chapter 2) indicated whether a given affordance had been appropriately enabled or not. The experiment collected data regarding the participant's behavior against predicted behavior. The independent variables included circumstances that in the real world would have evoked the affordances under investigation, and also presented various visual and auditory cueing that the conceptual model development suggested might lead to evoking the affordance. Analysis of the data shows whether or not these cues were effective in evoking the affordances under the tested conditions. This means that the first consideration in the across run analysis was the effect of the independent variables on the participant's behavior against predicted behavior.

The second consideration was the magnitude and significance of these effects, and the two way interaction of these effects. The calculation of the magnitude and significance of the main effects and two way interactions followed the approach laid out in Box et al. (1974). The present research adopted a $2_{IV}^{4-1}$ design with many replications for each of the experiments, which raised two main implications for interpretation of the results. The first implication was that main effects were confounded with three way interactions, and two way interactions were confounded with other two way interactions. The second implication was for the computation of the standard error, which was a key decision in the calculation of the significance of effects. The most common approach for computing standard error is to assume that the highest order interaction is not significant, and to use the value of that interaction as an estimate of standard error. However, the experimental design adopted in the present study was a fractional factorial, which brought into question an assumption about the significance of higher order interactions. The recommended approach in such circumstances is to estimate standard error from the variance between replications (Box et al, 1974, p. 319). This was the approach adopted in the present analysis. Finally, the adopted approach selected three times the standard error to be the level at which an effect or interaction was judged significant.

**Passability Analysis**

Table 19 summarizes the measured behavior as compared with predicted behavior for the passability experiment. Significant effects, i.e. those calculated values which fell within a one-sided 95% confidence interval of the predicted fraction rotating for the sample size collected, are marked with an asterisk and **bolded**. The prediction and predicted fraction rotating columns indicate what participants experiencing the given configuration in the real world would be expected to do. These predicted results, which were derived from Warren and Whang (1987), indicate that most participants in the real world would not rotate when presented with a wide door (i.e., one greater than 1.3 times their shoulder width), and most would when presented with a narrow door. The remaining columns indicated what members of each participant group actually did in the VE reported as fraction rotating. Fraction rotating was calculated as the number of participants who rotated in each treatment divided by the total number of participant exposed to that treatment. The Baseline (no cues) participant group's response is as predicted by Stappers (1999), namely that passability in a VE was inaccurately perceived, with only 10-50% rotating in the baseline VE conditions in which rotation was anticipated due to passage width and 30-40% rotating when it was not expected.  The Preliminary (i.e., pilot study) participant group showed a more consistent and somewhat improved perception of the passability affordance, with 55-65% making the expected rotation decision during VE conditions in which rotation was anticipated and 15-25% rotating when it was not expected.  The Final (i.e., formal study) participant group showed even greater consistency and improved perception in perceiving this affordance over the preliminary group, with 77.4-81% making the correct rotation decision and 17.9-26.2% rotating when it was not expected.  The Alternate (VE configurations presented in a different order) participant group showed erratic behavior, with 0-66.7% making the correct rotation decision and 0-33.3% rotating when it was not expected; with this effect likely being due to sample size.  The Header (passageways have a top) participant group was less consistent than the formal group but still had a high level of perception of this affordance, with 60%-80% making the correct rotation decision and 0-40% rotating when it was not expected.  Future research is required to determine if it is best to provide a header or not on passageways through which one is trying to afford passability.

Table 19: Fraction displaying behavior as compared to prediction for passability.

| Trt Cond. (See Table 16) | Predic-tion | Fraction Rotating Predicted | BASE-LINE | PRELIM-INARY | FINAL | ALTER-NATIVE | HEAD-ER |
|---|---|---|---|---|---|---|---|
| 1 | most rotate | 0.800 | 0.500 | 0.600 | *** 0.798** | 0.000 | *** 0.800** |
| 2 | few rotate | 0.200 | *** 0.300** | *** 0.200** | *** 0.179** | *** 0.333** | *** 0.200** |
| 3 | few rotate | 0.200 | 0.400 | *** 0.150** | *** 0.214** | *** 0.000** | 0.400 |
| 4 | most rotate | 0.800 | 0.300 | *** 0.550** | *** 0.774** | *** 0.667** | *** 0.800** |
| 5 | few rotate | 0.200 | 0.400 | *** 0.150** | 0.262 | *** 0.000** | *** 0.000** |
| 6 | most rotate | 0.800 | 0.100 | *** 0.650** | *** 0.810** | *** 0.667** | *** 0.600** |
| 7 | most rotate | 0.800 | 0.200 | 0.600 | *** 0.798** | 0.333 | *** 0.800** |
| 8 | few rotate | 0.200 | 0.400 | *** 0.250** | *** 0.238** | *** 0.000** | *** 0.000** |

***** - Calculated value is within one-sided 95% confidence interval, $\alpha = 0.05$.

Table 20 summarizes the calculated magnitude and significance of each main effect and their two way interactions on passability for the relevant participant groups. Significant effects, i.e., where the Effect is greater than three times the Standard Error, are marked with an asterisk and **bolded**. For the Final participant group, the passageway width was significant, as were the peripheral and bar cues. All two way interactions were significant. Realizing that rotation should only occur when the passageway is narrow and that the Baseline group showed that in the absence of cues, the participants were unable to accurately realize passability, the implication of the significant two way interaction is that the presented cues are sources of the participant's increased response to passageway width and therefore improved realization of passability. The Preliminary and Header groups reflect similar results. The failure of the Alternative group to reach significance for the bar cue is troubling; however this is likely a consequence of the small sample size. The Alternative group provides five samples, and the power of the resulting test is only 0.19, whereas the Final group with 86 samples has a power of one, the Baseline group with ten samples has a power of 0.64, and the Preliminary group with 20 samples has a power of one. The Header group, which provides three samples, has a power comparable to the Alternative group but found the bar cue to be significant. The Alternative configuration would require 24 total samples (19 more) to provide the same power as the Baseline group assuming constant variance.

Table 20: Effects of main factors and two-way interactions on passability.

| Effect | Baseline | Preliminary | Final | Alternative | Header |
|---|---|---|---|---|---|
| Bar cue (A) | N/A | * **0.038** | * **-0.018** | -0.100 | * **0.333** |
| Form cue (B) | N/A | -0.013 | -0.006 | 0.100 | 0.000 |
| Peripheral Cue (C) | N/A | * **0.038** | * **0.036** | * **-0.200** | 0.000 |
| Passage width (D) | * **0.100** | * **-0.413** | * **-0.571** | * **-0.600** | * **-0.333** |
| A-B or C-D | N/A | -0.013 | * **0.018** | -0.100 | * **-0.167** |
| A-C or B-D | N/A | * **0.038** | * **0.012** | 0.000 | * **-0.167** |
| A-D or B-C | N/A | * **0.038** | * **-0.012** | 0.000 | * **-0.167** |
| 3x Standard Error | 0.068 | 0.031 | 0.006 | 0.105 | 0.167 |

- Calculated as > 3x standard error.

**Catchability Analysis**

Table 21 summarizes measured behavior as compared with predicted behavior for the catchability experiment. Significant effects, i.e. those calculated values which fell within a one-sided 95% confidence interval of the predicted fraction rotating for the sample size collected, are marked with an asterisk and **bolded**. The prediction and predicted fraction catching columns indicate what participants experiencing the given configuration in the real world would be expected to do. These predicted results, which were derived from Oudejans et al. (1996), indicate that most people will judge a ball catchable if it lands within a circle whose radius is 1.2 times their actual catchable range, i.e., they over estimate. The predicted values in the table therefore are driven by the experimental configuration's value for shot range, either catchable or not. The remaining columns indicated what members of each participant group actually did in the VE reported as fraction judging the ball as catchable. The remaining columns indicate how the various groups actually judged the ball in the virtual environment. The Baseline (no cues) participant group's response indicates that participants were largely unable to judge the ball correctly, with 40-90% of participants judging catchable balls as such and 30-90% misjudging uncatchable balls. This is an expected result as the experimental design anticipated that catchability would not be realized in conventionally designed VEs much as passability is not. The Preliminary participant group showed a significant improvement, with 80-95% of participants judging catchable balls as such and only 0-15% misjudging uncatchable balls. The Final participant group also did well, with 88-96.4% of participants judging catchable balls as such and only 11.9-22.6% misjudging uncatchable balls. The Final 021-043 group, which had a modified thud cue, demonstrated marginal improvement over the Final group at large, particularly with respect to judging uncatchable balls, with only 4.3-17% misjudging such balls. The Alternative group showed results comparable with the Final group. All four of these groups found that the response to configuration 15 (no stick cue, thud cue, peripheral cue, and catchable) fell outside of the 95% confidence interval for the predicted results. The data provide no strong indication of why this result occurred. Reports from participants about the distracting nature of the peripheral and thud cues may mean that participants were too distracted to make a valid judgment as to the ball's catchability with this particular combination. Future research should carefully address the best way to combine such cues.

Table 21: Fraction displaying behavior as compared to prediction for catchability.

| Trt Cond. | | | Faction Catching | | | | | |
|---|---|---|---|---|---|---|---|---|
| (See Table 16) | Pred-iction | Predicted | BASE-LINE | PRELIM-INARY | FINAL All | FINAL-021-043 | ALTER-NATIVE | HEAD-ER |
| 9 | Most Catch | 0.800 | 0.500 | * **0.850** | * **0.881** | * **0.894** | * **1.000** | * **1.000** |
| 10 | Few Catch | 0.200 | 0.500 | * **0.150** | * **0.226** | * **0.170** | * **0.000** | * **0.200** |
| 11 | Few Catch | 0.200 | 0.900 | * **0.000** | * **0.119** | * **0.043** | * **0.000** | * **0.000** |
| 12 | Most Catch | 0.800 | * **0.900** | * **0.800** | * **0.964** | * **0.979** | * **1.000** | * **1.000** |
| 13 | Few Catch | 0.200 | 0.400 | * **0.050** | * **0.143** | * **0.085** | * **0.000** | * **0.000** |
| 14 | Most Catch | 0.800 | * **0.900** | * **0.950** | * **0.964** | * **0.979** | * **1.000** | * **0.800** |
| 15 | Most Catch | 0.800 | 0.400 | 0.000 | 0.119 | 0.085 | 0.000 | * **0.600** |
| 16 | Few Catch | 0.200 | 0.300 | * **0.100** | * **0.179** | * **0.064** | * **0.000** | * **0.200** |

***** - Calculated value is within one-sided 95% confidence interval, $\alpha = 0.05$.

Table 22 summarizes the calculated magnitude and significance of each main effect and their two way interactions on catchability for the participant groups. Significant effects, i.e., where the Effect is greater than three times the Standard Error, are marked with an asterisk and **bolded**. Table 22 distinguishes between the Final-All and Final 021-043 groups, because the thud cue was modified as a result of observations during the experimental runs as discussed earlier. The Baseline, Final, and Final 021-043 participant groups found all of the main effects (cues) significant. Likewise, all two way interactions were significant. Realizing that the catchable judgment should only occur when the shot range was long, and that the Baseline group showed that, in the absence of cues, participants were generally unable to accurately realize catchability, the implication is that the affording cues were sources of the participant's more accurate response to shot range.

Table 22: Effects of main factors and two-way interactions on catchability.

| **Effect** | **Baseline** | **Prelim-inary** | **Final All** | **Final 021-043** | **Alter-native** | **Header** |
|---|---|---|---|---|---|---|
| Stick Cue (A) | N/A | * **0.275** | * **0.268** | * **0.271** | * **0.150** | * **0.250** |
| Thud Cue (B) | N/A | * **-0.275** | * **-0.208** | * **-0.239** | -0.050 | * **-0.250** |
| Peripheral Cue (C) | N/A | * **-0.175** | * **-0.196** | * **-0.218** | * **-0.150** | * **-0.250** |
| Shot Range (D) | * -0.150 | * **-0.575** | * **-0.565** | * **-0.644** | * **-0.750** | * **-0.750** |
| A-B or C-D | N/A | * **0.175** | * **0.185** | * **0.186** | * **0.150** | * **0.250** |
| A-C or B-D | N/A | * **0.225** | * **0.173** | * **0.165** | 0.050 | * **0.250** |
| A-D or B-C | N/A | * **-0.175** | * **-0.196** | * **-0.218** | 0.050 | * **-0.250** |
| 3x Standard Error | 0.061 | 0.012 | 0.004 | 0.004 | 0.068 | 0.000 |

* - Calculated as > 3x standard error.

## Flyability Analysis

Table 23 summarizes the measured behavior as compared with predicted behavior for the flyability experiment. Significant effects, i.e. those calculated values which fell within a two-sided 95% confidence interval of the predicted fraction rotating for the sample size collected, are marked with an asterisk and **bolded**. A two-sided confidence interval is appropriate, because the flying predictions occur at three levels. The prediction and predicted flying columns indicate what participants experiencing the given configuration in the real world would be expected to do. Flyability is not an affordance that naturally exists for humans, so the circumstances under which it is enabled were unknown prior to this study. This is the reason that the flyability experimental configuration includes two object properties (window height and width). Whereas the passability experiment configuration could leverage from Warren and Whang (1987) that passageway width was the critical object property and the catchability experiment could leverage from Oudejans et al. (1996) that shot range was the critical object property, the flyability experiment had no such prior results. The conceptual model postulated that flyability was a spatial affordance; therefore the predicted results are postulated based on parallels in flyability to passability. As a result, the flyability experiment has three levels of prediction under the assumption that there may be some interaction between window height and width. The passability studies discussed (Warren, 1984; Warren & Whang 1987; Marik, 1987) all suggest object properties along the vertical axes (frontal or sagittal) of the observer, such as passage width and stair height. Therefore, the predictions are that participants will be more likely to fly when faced with a low, wide window, and less likely to fly if a window is either narrow or high, and still less likely if the window is both high and narrow. The remaining columns indicated what members of each participant group actually did in the VE reported as fraction flying. The Baseline (no cues) participant group responded strongly to the window height object property – configuration four through eight all have the window height set to "high", and all of these values for the Baseline group fall within the 95% confidence interval. This is strong evidence that height to fly over is a critical object property for flyability. The Preliminary participant group showed results inconsistent with the Baseline, implying that the cues added had an effect but not the desired one of bringing measured behavior in line with predicted behavior (only three configurations are within the 95% confidence interval). The Final participant group showed significant improvement in correlating observed behavior with predicted behavior (six configurations are within the 95% confidence interval). The failure of the Final group to exhibit every aspect of the predicted behavior is not of particular concern, since predicted values were not based on prior studies. Flyability is not an affordance in the real world, so there were no studies on what constitutes an evoking circumstance prior to the present research, or what its threshold values are, as opposed to passability and catchability. The results provide strong evidence that window height and width are evoking circumstances for flyability, and provide a basis for predicting their threshold values for enabling realization of flyability. For example, changing the predicted fraction of ‘few’ flying from 0.200 to 0.300 would have resulted in the Final group perfectly reflecting predicted behavior. These results suggest that flyability is readily afforded in VEs, which is interesting given that it is a supernatural phenomenon.

Table 23: Fraction displaying behavior as compared to prediction for flyability.

| **Trt Cond. (See Table 16)** | **Prediction** | **Predicted** | **Fraction Flying** BASE-LINE | PRELIM-INARY | FINAL | ALTER-NATIVE | HEADER |
|---|---|---|---|---|---|---|---|
| 17 | Some Fly | 0.500 | 0.100 | * **0.468** | * **0.468** | * **0.000** | * **0.200** |
| 18 | Most Fly | 0.800 | 0.200 | 0.450 | * **0.726** | * **0.667** | * **0.400** |
| 19 | Most Fly | 0.800 | 0.300 | 0.400 | * **0.655** | 0.000 | * 0.200 |
| 20 | Most Fly | 0.800 | 0.400 | 0.400 | * **0.679** | 0.000 | * **0.400** |
| 21 | Some Fly | 0.500 | * **0.300** | * **0.450** | * **0.429** | * **0.667** | * **0.600** |
| 22 | Few Fly | 0.200 | * **0.100** | 0.500 | 0.393 | * **0.333** | * **0.200** |
| 23 | Few Fly | 0.200 | * **0.200** | 0.600 | 0.440 | * **0.333** | 0.600 |
| 24 | Some Fly | 0.500 | * **0.600** | 0.200 | * **0.393** | * **0.333** | 0.000 |

***** - Calculated value is within one-sided 95% confidence interval, $\alpha = 0.05$.

Table 24 summarizes the calculated magnitude and significance of each main effect and their two way interactions on flyability for the relevant participant groups. Significant effects, i.e., where the Effect is greater than three times the Standard Error, are marked with an asterisk and **bolded**. The Baseline group demonstrated that in the absence of cues, participants were unable to realize flyability as predicted (only 2 configurations < 3 * Standard Error). The Preliminary group, which had prototypes of the cues present, demonstrated a realization of flyability much more in line with the predicted values (5 configurations < 3 * Standard Error). The Final participant group showed consistent improvement with every configuration group in line with the predicted result. This demonstrated that the modifications made after the preliminary study better enabled the realization of flyability as predicted. The single best example is the dramatic improvement of the magnitude of the Height effect, which was 2725% greater in the Final as compared to the Preliminary group (-0.218 versus 0.008). All two way interactions in the Final group were significant. The implication is that window height and size are primary determinates of flyability (much as passageway width is for passability), and that wings and peripheral cues are sources of a participant's decision to fly. The Preliminary, Alternative, and Header groups do not reflect similar results. These effects are weak (relative to those measured in passability and catchability) and thus may be related to the small sample size. The power of the Alternative group (sample size 5) is 0.05 for window height; the power of the Header group (sample size 3) is 0.06 for wings. The Alternative group would require a total of 55 samples (50 more) and the Header would require 129 total samples (126 more) to achieve the same power as the Baseline sample assuming constant variance.

Table 24: Effects of main factors and two-way interactions on flyability.

| Effect | Baseline | Preliminary | Final | Alternative | Header |
|---|---|---|---|---|---|
| Wings Cue (A) | N/A | * **-0.092** | * **0.050** | * **-0.150** | 0.083 |
| Peripheral Cue (B) | N/A | * **-0.067** | * **0.038** | -0.050 | * **-0.250** |
| Height of Window (C) | 0.050 | 0.008 | * **-0.218** | 0.050 | * **0.250** |
| Width of Window (D) | * **0.150** | * **-0.117** | * **0.056** | -0.050 | * **0.250** |
| A-B or C-D | * **0.550** | * **-0.108** | * **-0.062** | -0.050 | -0.083 |
| A-C or B-D | N/A | * **-0.083** | * **-0.091** | * **-0.350** | * **-0.250** |
| A-D or B-C | N/A | -0.008 | * -0.032 | -0.050 | 0.083 |
| 3x Standard Error | 0.058 | 0.037 | 0.008 | 0.135 | 0.208 |

- Calculated as > 3x standard error.

## <u>Presentation Form Analysis</u>

The experiment also supported a comparison of the perception of the tested affordances in two different presentation media: a HMD or a project screen. Table 25, shows the t-test value computed for each affordance between the HMD and Screen presentation media. The difference between the HMD and the Screen presentation media were found to be significant (t-test, α=0.05), whereas the difference was not found to be significant in the flyability experiment.

Table 25: Affordances impact on presentation media.

| Affordance | t - calculated | t - table | Conclusion | Interpretation |
|---|---|---|---|---|
| Passability | *3.704 | 1.895 | Reject | HMD is different than Screen |
| Catchability | *2.744 | 1.895 | Reject | HMD is different than Screen |
| Flyability | 0.953 | 1.895 | Fail to Reject | HMD is not shown to be different than Screen |

* p<0.05

A final issue concerns the participant's awareness of the cues presented. This awareness was not measured directly, but was tested by survey. Figure 17 shows the percentage of participants reporting that a particular cue form was noticed and the corresponding 95% confidence interval, as derived from the responses to the "Affordances in Virtual Environments – Cue Perception Questionnaire". The "other" category addresses participants reporting cues which were not actually present in the task room. The data indicate that typically less than half of the participants noticed any specific cue. The two exceptions are 56% of the participants noticed the passability peripheral cue and 51% noticed the catchability shot range cue. Forty seven percent of the participants noticed the flyability window height cue. In regards to passability, significantly more participants noticed the peripheral cue than the form cue. In regards to catchability, the shot range was noticed by significantly more participants than the stick, thud, and other cues. In regards to flyability, no participant reported noticing the flyability wing cue whose 95 confidence interval does not overlap with any other flyability cue. The height cue for flyability was noticed by significantly more participants than any other flyability cue.  Note that other phantom cues were noticed about the same rate as cues actually present, indicating that the actual cues were not an important source of confusion or distraction for participants.  The most common non-existing cue reported was the reporting of a different affordance cue, such as the presence of a sound cue for passability. Participants also reported non-existing cues such as changes in color, light, shading, or size of apertures.  Several participants reported "never" or "always" performing a function such as rotating, judging catchable, or flying, but the actual data show that every participant varied their behavior to a greater or lesser extent (see Tables 19-24).

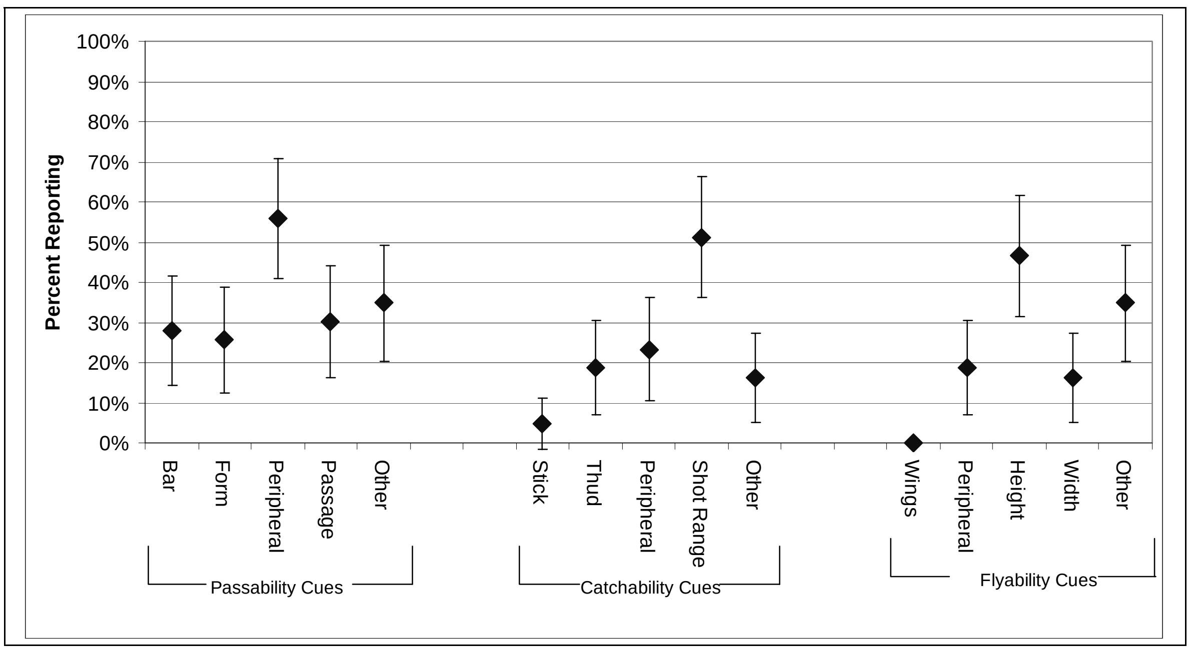


Figure 17: Cues noticed by participants (confidence interval, $\alpha=0.05$).

# CHAPTER 5: DISCUSSION

The discussion proceeds from the most specific and least general implications of the study to the most general implications. It begins by exploring the implications of the experiment's results for the six hypotheses developed in the Background chapter, which was the immediate objective of this study. Then, the discussion explores the implications of the experiment's results for the more general question of sensory substitution schemes. Finally, the discussion explores the implication of the experiment's results for the general question of design enabling affordances.

## Implications for the Hypotheses

The objective of the present research was to enable the perception of affordances in virtual environments. Toward this end, the realization of three affordances was considered: passability, catchability, and flyability. Two hypotheses were developed for each affordance in turn.

### Passability Hypotheses

The first hypothesis developed regarding the passability affordance was:

**Hypothesis**: Visual cues for body stature substituting for absent multimodal sensory stimulation and body stature information can enable the realization of the passability affordance in virtual environments, as confirmed by testing for the ratio of 1:1.3 for comfortable passability.

The results generally support this hypothesis. The results for the baseline participant group (see Table 20), which were not provided with cues to enhance the realization of affordances, support the position that participants generally do not correctly perceive the affordance of passability when simply presented with visual information about passageways (e.g., the width of a doorway). These results are in line with Stappers' (1999) findings that VE participants do not perceive passability in conventionally designed VEs in a manner similar to that experienced in the real world. For the formal group (see Table 19), which was provided with substitution cues, two of the visual cues tested, the bar and the peripheral cues, significantly affected participant's passability behavior bringing it in line with behavior observed in real world situations, with participants rotating their body when passage widths were less than 1.3 times their body width (Warren & Whang, 1987). This is a very encouraging finding, suggesting that visual cues can enable the correct realization of passability. This could be particularly important for those attempting to train psychomotor skills in a virtual environment, such as a Marine's behavior during a room clearing exercise.

The fact that the bar cue was not effective in the alternative VE (see Table 19), could suggest that cues may have limited generalizability in their effectiveness to realize affordances. This is a troubling finding, as it suggests that one would have to test the effectiveness of a given cue in each and every VE it is to be used in. An alternative interpretation of this result is that it is simply an effect of small sample size, which is supported by the power analysis as discussed.

The fact that the form cue was not effective (see Table 19), is troubling, because form cue is generally regarded as more realistic that the bar cue, and the expectation is that more realistic cues lead to improved realization of the affordance. An alternative explanation is that the participants found the form cue disconcerting because it presents the head cue below eye level, close to knee level. In this case, the increased realism of the cue may work against its efficacy as the head would not be correctly placed. Observers might have had trouble interpreting the cue as indicating head and shoulders, because to do so they would have to translate the cue from its presentation at knee level to head level. This latter interpretation is supported by the fact that the magnitude of the form cue effect as on the border of significance (an effect of -0.600 versus the level of significance of

0.600, see Table 20), indicating that it had some effect on users but significantly less than for the bar or peripheral cues.

The Background chapter argued that there are three key sources of information required in order to realize the passability affordance, and that the last is impoverished in a VE (see Table 5). Specifically, knowledge of shoulder width, which arises from experience and ongoing kinesthetic and vestibular mode stimulation, is absent. The bar and peripheral cues were shown effective by the passability experiments in substituting visual data for this missing kinesthetic and vestibular stimulation (see Table 20). This supports the supposition based on Storms (2002) and Shimojo and Shams (2001) that the strong association between spatial perception and visual stimuli can indeed be exploited to enable the perception of passability.

The second hypothesis developed regarding the passability affordance was:

**Hypothesis**: An appropriate minimal form for visual cues of body stature can be found, as confirmed by measuring threshold responses to a variety of cues.

The results indicate that the bar and peripheral cues may be able to serve as minimal forms for a visual cue of body stature (see Table 20). This directly supports the conceptual model (see Figure 4) developed, which contended that passability is not correctly perceived in VEs because VE users do not perceive their own shoulder width, and a minimal amount of information providing this cue would enable perception of the passability affordance.

However, the form cue did not afford passability (see Table 20). The form cue consisted of a 3-dimensional simplified form of a head, neck, and shoulders; whereas the bar cue consisted of a simple rectangular bar the width of the participant's virtual shoulders, and the peripheral cue consisted of hashing outside the width of the shoulders. In some respects the outcome is surprising because the form cue would typically be considered more realistic than the bar cue, and the usual expectation is that more realistic cues improve performance (Durlach & Mavor, 1995; Cutting, 1997). On the other hand, the form cue includes information not relevant to realizing passability such as the height of the head off of the shoulders. The efficacy of the bar and peripheral cues is most promising, as it indicates that non-specific cues that simply indicate what is "out of bounds" have the ability to realize the passability affordance.

The experiment findings produce implications for VE designers seeking to enable the realization of passability in terms of things a designer can easily control: 1) the properties of objects in a VE; 2) characteristics of the user in the VE; and 3) the action capabilities of the user in the virtual environment. The results imply that a critical object property or evoking circumstance for passability in VEs is passageway width, because when the width was less than the virtual shoulder width, the passability affordance was realized. This is consistent with real world studies (Warren, 1984; Warren & Whang 1987; Marik, 1987). One could argue that the edges around passageways, rather than the passageway width, are the critical object properties eliciting the passability affordance. In the present study, the majority of edge cues derived from the simple intersection of the wall with the floor, with no particular emphasis. Further, the far wall, i.e., the wall beyond the one with the passageway, was the same color and texture as the passageway wall, so there was no drastic contrast used between passageways and surrounding wall object properties. Thus, the findings support the premise that passageway width is a critical object property for realizing the passability affordance.

In terms of the physical characteristic required for realizing passability, the comparison of the baseline and formal groups suggests that shoulder width is critical to enable the realization of passability. When participants were presented with visual cues as to the shoulder width of their virtual body, they tended to rotate their virtual bodies when passageway width was less than 1.3 times the cued shoulder width; far fewer participants chose to rotate when these cues were not provided. In the present study, the simplest physical characteristic cue that proved effective was a horizontal bar, located at the participant's virtual body position, which rotated around the vertical axis to indicate the participant's degree of rotation. Designers should consider endowing their virtual avatars with cues about width in order to afford passability.

Finally to enable the realization of passability, the VE must provide a means for users to rotate the virtual body. In the present study, the rotation action capability was provided by depressing the left mouse button. While this approach was effective, it is not the most intuitive of approaches, as it involves a metaphoric (i.e., left button=rotate) rather than a direct mapping (e.g., turn of one's actual body evokes the same effect in one's virtual body). It is likely that providing this action capability by harder (e.g., depressing two buttons) or easier (e.g., measuring head rotation angle) would change the magnitude of the cueing effects.

### Catchability Hypotheses

The first hypothesis developed regarding the catchability affordance was:

**Hypothesis**: Visual and auditory cues for acceleration and velocity substituting for absent multimodal sensory stimulation and action capabilities information can enable the realization of the catchability affordance in virtual environments, as confirmed by testing for the 1:1.2 ratio of actually catchable balls to those perceived catchable.

The results generally support this hypothesis. The results for the baseline participant group indicated that participants can correctly judge catchability in the absence of cueing with a low level of accuracy (see Table 22); however, adding cues improves the quality of such judgments. More specifically, the results for the baseline group demonstrate that in the absence of substitution cues participants were able to weakly realize the catchability affordance as evidenced by the decision to rotate (an effect of -0.150), but much more strongly realize the affordance in the presence of the substitution cues (an effect of -0.644). While the visual cues (stick and peripheral cues) were effective in realizing the catchability affordance in both the formal VE and the alternative VE, the thud was only effective in the formal virtual environment (see Table 22). This is surprising given the relationship between the auditory modality and temporal perception and suggests that the optimal design of an auditory cue for realizing the affordance of catchability is yet to be identified. It also could suggest that the temporal component of the catchability task as developed in this study was not as influential as would normally be experienced during a catching drill. To address these concerns, future research should explore different forms of audio cues and their relationship to the realization of temporal affordances. For example, the thud cue implemented in the experiment was actually more of a high pitched "beep". It may be that a cue closer to a footfall would produce a stronger effect. As implemented, the thud cue used the space between thuds as indirectly related to speed (thuds closer together indicated faster speed). It may be that other cues, such as varying pitch with speed, might be more effective.

The argument developed in the Background chapter argued that there are seven key sources of information required to realize the catchability affordance, and that two of these are impoverished in a VE (see Table 6). Specifically, self-velocity and self-acceleration, both of which arise from experience and ongoing kinesthetic and vestibular mode stimulation, are absent. Both visual cues (stick and peripheral) and an auditory cue (thud) were shown effective by the catchability experiment (see Table 22). The effectiveness of the auditory cue is not surprising because the auditory modality is generally highly effective in conveying information when reaction time is essential for effective task performance (Popescu et al., 2002; Storms, 2002). The visual-auditory cue interactions were all significant too, which supports Shimojo and Shams' (2001) point as to the ability of auditory stimuli to intensify visual stimuli. These findings support the supposition developed in the Background chapter that the strong association between temporal perception and auditory and visual stimuli interaction can be exploited to enable the perception of catchability.

The second hypothesis developed regarding the catchability affordance was:

**Hypothesis**: An appropriate minimal form for visual and auditory cues of locomotion can be found, as confirmed by measuring threshold responses to a variety of cues.

The results suggest that a range of cues (both visual and auditory) can be leveraged to enable the perception of catchability, which supports this hypothesis. The conceptual model developed implied that auditory information would be the most important source of information for enabling the perception of catchability, therefore the result that visual cues were comparable in their effectiveness to realize this affordance is somewhat surprising. There are a number of possibilities that might explain why auditory information was not more effective– the size of the room, the time available to make the judgment, the relative speed of the intersecting objects and so forth. The cannon balls were shot with velocities that led to their impact within about two to three seconds and traveled no more than eight meters; therefore there was little time to integrate the audio cue. If the situation had permitted a longer period before the ball impacted, it is possible that audio feedback concerning acceleration and self-velocity might have been more significant. Thus, while this substitution aimed at replacing missing exterocepter, interceptor, and propriocepter cues associated with accelerating to catch a ball, the period of bodily movement may have been too short for these cues to act as a movement metronome.

The adjustment of the thud cue after the first twenty runs provides strong evidence as to the minimal level for this cue in particular. The design intent of the cue was to provide thuds, or short sounds, at a slow rate when the participant's speed was low and a faster rate when the participant's speed was greater. The original implementation resulted in an almost flat curve in the range of speeds actually exercised. The thud cue revision beginning with F-021 produced a curve with a noticeable rate change in the thuds. Although the change in the cue was fairly dramatic, the impact on the effect was not (moving from -0.208 to -0.239, with both effects significant). This suggests that any audio cue related to movement may significantly aid participants in judging the catchability affordance. The slight increase in cue effectiveness, however, suggests there may be some benefit to using noticeable rate changes. Future research should consider if variable rates for auditory cues have the potential to further enhance the realization of the catchability affordance.

The fact that participants could realize the catchability affordance in the absence of the substitution cues indicates that this affordance is not as handicapped as passability by the absence of sensory data in VEs at the boundary values tested. As discussed, catchability should involve a strong temporal component, and the visual sensory information required to make speed judgments (e.g., position in the environment) is present even without the additional audio substitution cues.

The results imply that a critical object property, or evoking circumstance, for catchability in VEs is the height of the ball, which is one of the effects of how the balls where shot out of the cannon. The balls shot as uncatchable had a lower trajectory than the balls shot as catchable, and participants reported cueing off ball height in the cue perception questionnaire. Future research could repeat this experiment with a wider range of trajectories. This cueing off of the trajectory of the ball is consistent with real world studies (Oudejans et al., 1996). One could argue that ball rotation, rather than the ball height, is the critical object property eliciting the catchability affordance. However, the balls in the present study did not include rotation, so it is unlikely that rotation is necessary to enable the realization of catchability. Thus, the findings support the premise that ball height is a critical object property for realizing the catchability affordance.

The comparison of the baseline and formal groups suggests that reach range and self- velocity are the physical characteristics required to realize catchability. When participants were presented with visual cues as to the reach range of their virtual body and visual (a leaning stick) or auditory (footstep sound) cues correlated with the velocity of their virtual movements they tended to have an enhanced sense of catchability as compared to baseline participants who lacked such cues. In the present study, the simplest physical characteristic cue that proved effective was a vertical bar (i.e., stick), located in the frontal plane of the participant's virtual position, which rotated around the horizontal axis to indicate the participant's speed. The "thud" cue, a series of variable auditory "beeps" related to speed, was found to be an effective audio cue. Designers should consider endowing their virtual avatars with such cues in order to afford catchability.

Finally to enable the realization of catchability, the VE must provide a means for users to move their virtual body. In the present study, movement was directly controlled by mouse position. No capability for actually catching such as extending arms, opening hands, or grasping, was provided to the participants. Such action capabilities should be considered in future research.

## Flyability Hypotheses

The first hypothesis developed regarding the flyability affordances was:

**Hypothesis**: Visual cues for space required to fly substituting for absent multimodal sensory stimulation and action capabilities information can enable the realization of the flyability affordance in virtual environments, as demonstrated by users choice of flying when presented with multiple, valid forms of locomotion.

The results generally support this hypothesis. Participants chose to fly without any visual cues (see Table 24), but the presence of visual cues encouraged participants to choose to fly more often and tended to align the decision to fly with situations that made sense, such as in the presence of lower and wider windows. Both visual cues (i.e., wings and peripheral cues) were effective in affording flying in the formal VE, however, in the alternate VE only the wings were effective. This suggests that the wings cue may be the most appropriate cue for affording flying. Further, the addition of a header seems to have enhanced the perception of the flyability affordance for the peripheral cue (see Table 8).

The Background chapter argued that there are three key sources of information required in order to realize the flyability affordance, and that the last is impoverished in a VE (see Table 7). Specifically, knowledge of spatial requirements for flying, which arises from experience and ongoing kinesthetic and vestibular mode stimulation, is absent. The wing and peripheral cues were shown effective by the flyability experiments in substituting visual data for this missing kinesthetic and vestibular stimulation (see Table 24). This supports Storms' (2002) and Shimojo and Shams' (2001) supposition that the strong association between spatial perception and visual stimuli can be exploited to enable the perception of flyability.

The second hypothesis developed regarding the flyability affordance was:

**Hypothesis**: An appropriate minimal form for visual cues for flying can be found, as confirmed by measuring threshold responses to a variety of cues.

The results suggest that a range of visual cues (wings and peripheral) can enable the perception of the flyability affordance, which supports this hypothesis. Flyability is different from passability and catchability in that it is not an affordance realized in the real world. Therefore, the object properties, or evoking circumstances, that evoke realization of the flyability affordance are unknown, whereas it is known that passage width evokes passability and the distance a ball is shot or thrown (i.e., the "catchable" cue) evokes catchability. It is of interest to discover what evoking object properties and what physical characteristics are engaged in realizing the flyability affordance.

As the experiment only considered two levels for each factor, it will not be possible to discover an exact ratio such as 1.3: 1 for passability (Warren & Whang, 1987) or 1.2:1 for catchability (Oudejans et al., 1996), but an approximate value can be derived.

The two object properties tested in this study, window width and window height, were selected because they represent the two planes of movement involved in flying as opposed to the single plane for passability. The results demonstrate that both of these object properties were significantly associated with the realization of flyability, although only widow size evoked flyability in the absence of cues (see Table 24).

The preliminary study as compared to the final formal experiments provided valuable information specific to the threshold of the window height cue. The most important change in the flyability cues from the preliminary study to the final study was the change in window height. Window height was not found to be a significant factor for the preliminary group (0.008) but was significant for the final group (-0.218), for which the windows were lowered such that users could see the windows they could fly through. The original values for the window height which failed to evoke flyability were one and one half meters for the low value and two and one half meters for the high value. The revised values after the pilot study results were to one and two meters respectively (see Table 14). The window width was 1.5 meters for the low value and 2 meters for the high, and was not modified throughout the experiment.

It is unknown what physical characteristic forms the appropriate ratio for flyability, however, the choice to fly or not is a choice of locomotion style similar to passability. The passability studies (Warren, 1984; Warren & Whang 1987; Marik, 1987) all suggest physical characteristics along the vertical axes (frontal or sagittal) of the observer, such as shoulder height and knee height. Therefore, this analysis uses eye point as a first approximation for the vertical plane and shoulder width for the horizontal plane. Eye point in all of the experiments was 1.8 meters and shoulder width was 0.8 meters. Therefore, the approximate ratio $\frac{WindowHeight}{EyePointHeight} = \frac{1}{2}$ appears to evoke flyability. Likewise, the approximate ratio $\frac{WindowWidth}{ShoulderWidth} = \frac{2.5}{1}$ appears to evoke flyability. Future studies should investigate the efficacy of these proposed ratios.

Flyability is not like passability and catchability, which are affordances that have been measured in the real world and thus evidence exists as to their significant object properties, observer characteristics, and action capabilities. Flyability is not a natural capability of humans, and therefore the experiment results here are not confirming that cuing can enable the realization of an affordance in a similar way to affordances in reality; instead the experiment is showing how a VE can enable the realization of an affordance only present in a virtual environment. This is particularly important as one major purpose of VEs is to afford things which reality can not.

The experiment's findings imply that the object properties, or evoking circumstances, for flyability are window height (lower bound) and window width (side bound). Therefore, to enable the realization of flyability, objects in a VE to be flown through should include edges and gaps that relate to lower and side-to-side bounds of the passage to be flown through; with initial ratios being those proposed above (1:2 for window height to eye point eye and 2.5:1 for window width to should width). Designers should ensure that for objects intended to evoke flying, the lower bounds and side-to-side bounds are not so high and so tight as to create a burden to fly. The present study demonstrated that windows whose object properties include a lower sill (i.e., the header, see Table 24) tend to more easily evoke flying; those whose properties include wide aperture also tend to more easily evoke flying. However, there is some lower bound beyond which the user will not fly –

participants did not choose to fly out of the passageway, despite the fact that its threshold was lower than the lowest window.

The comparison of the baseline and formal groups suggests that shoulder width and eye point height are likely to be, or are strongly correlated with, the physical characteristics required to realize flyability. When participants were presented with virtual wings or peripheral cues they tended to chose to fly more consistently than baseline participants who lacked such cues (see Table 24). In the present study, the simplest physical characteristic cue that proved effective was the wings cue. The wings cue was located above the virtual body' shoulder position, and rotated around the vertical axis to indicate the participant's degree of rotation. Designers should consider endowing their virtual avatars with such cues in order to afford flyability.

Finally to enable the realization of flyability, a VE must provide a means for users to make their virtual body fly. The experiment's findings imply that the implementation of the flying action capability, depressing the right mouse button, was sufficient for realizing flyability. The experiment only tested this one implementation of the flying action capability – and it is likely that environments which require more effort by the participant to fly (e.g., pressing two keys instead of one) would likely find different specific values for the ratios. If the burden created is too great, users would likely choose a different (easier) locomotion mode.

## Implications for Sensory Substitution Schemes

The argument developed in the Background chapter proposed that sensory substitution schemes could succeed in replacing missing sensory modality in VEs and result in enabling realization of affordances. The argument proposed that a successful sensory substitution scheme would have to do three things:

1) Replace sensory modalities not represented in the virtual environment.

2) Outweigh natural stimuli not correlated with the virtual environment.

3) Exceed response thresholds in the modality used for the substitution.

The sensory substitution schemes adopted by the experiment generally accomplished all three of these goals, as the cues presented successfully enabled the realization of the affordances tested at least in some if not all of the conditions tested. This implies that designers can develop VE designs that exploit sensory substitution schemes that enable realization of affordances as desired; however, it also implies the efficacy of such schemes may not be universal, potentially depending on the cue used or the VE design itself. Further, the results from this study suggest that the failure demonstrated by Stappers (1999), in which participants in a VE did not realize the affordance of passability, may potentially be overcome at least for the affordances and the substitution schemes herein tested.

The experimental results also support the general scheme of providing visual cues substituting for absent modalities when the affordance in question is primarily spatial, and a combination of visual and auditory cues when the affordances is primarily temporal. Visual cues were effective for enabling the realization of both passability and flyability, which depend on cross modal and spatial perceptions. The audio and the visual cues were effective for enabling the realization of catchability, which depends on cross modal and temporal perceptions.

Finally, the experimental results demonstrate that substitutionary cues need not distract or otherwise interfere with users. Asked to report on the cues that they noticed, participants reported noticing cues that did not exist at approximately the same rate as they did cues they actually did exist. One effective cue, the wing cue for flyability, was reported by no user. This should be investigated by further research as to how this cue was effective and not noticed. The wing cue as compared to the other cues was in a different location (located high in the field of view), was a different color (blue as opposed to peach), and was presented in a different style (somewhat more complex). It is not known from the existing results which of these effects assisted in reducing the impact of the cue while retaining its effectiveness. This is consistent with Rensink et al's (1997) conclusion that observers never form a complete, detailed representation of their surroundings. This result is important because it indicates that design approaches that depend on substituted stimuli may be acceptable to VE users. If participants had noticed the cues, it could have been argued that providing cues via substituted stimuli is distracting from the intended experience in a virtual environment. The survey results indicated that at least some cue forms are generally not noticed by the average user, even though they may significantly affect actual behavior.

## Implications for Enabling Affordances In Virtual Environments

The Background chapter synthesized a set of principles, which were asserted to have implications for designers seeking to enable correct perception in virtual environments. The following discussion treats each in turn in light of the present research.

**Affordances depend on objects in the environment**. This principle was developed as a self-evident observation about different object properties/behaviors resulting in different affordances. The existing affordance literature made this assertion only about objects in the real world, and questioned the ecological validity of virtual worlds such as those induced by paintings. The present research has shown that visual and auditory cues in a VE will in fact lead to the realization of different affordances. Further, the range of participant behavior (i.e., passability, catchability, flyability) in response to the range of cues associated with enabling the realization of a specific affordance demonstrates that this principle applies in VEs as well as reality. Finally, St. Amant (1999) argued that an organism can perceive the same affordance from multiple objects, but some objects provide a stronger (better fit) affordance than others, and the present research supports this supposition. For example, in the passability experiment the response to the form cue was less than the response to the bar cue. This is evidence that the bar cue better fits the passability affordance. The implication is that designers can endow objects with properties that are relevant to an individual's purpose within a VE system and thus afford desired skills and appropriate behaviors.

**Affordances depend on the organism's action capabilities**. This principle was again developed as a self-evident observation that different action capabilities result in different affordances. Warren (1984), Warren and Whang (1987), Bingham and Muchisky (1992), and Oudejans et al. (1996) all discuss the impact of action capabilities on the perception of affordances. This principle is difficult to establish in the real world because an organism usually possesses a given set of action capabilities, which are not easily extended. There are exceptions at the margins for individuals with extraordinary limitations (such as loss of legs) or abilities (such as double jointed-ness). In contrast, it is possible in a VE to extend significantly different action capabilities to all participants. The example in the present research was flying, and the results of the present study suggest that affording this added action capability results in different participant behavior. Participants chose to fly when presented with cueing that enabled the realization of this affordance. The conclusion is that VE designers may be able to empower users with unusual capabilities and expect them to be used if appropriate cueing information is available.

**Affordances depend on physical characteristics of the observer**. Warren (1984) , Warren and Whang (1987), Marik (1987), Bingham and Muchisky (1992), Oudejans et al. (1996), and Turvey et al. (1999) all demonstrated that affordances relate to the physical characteristics of the observer. This principle was at risk in VE design, as there was no assurance that participants would readily pick up their virtual characteristics and perceive affordances on their basis. The results demonstrate; however that participants did pick up their virtual characteristics as demonstrated, for example, by the relatively low variance in the passability experiment, and in that there was no correlation between user height and their decision to rotate. The implication for designers is that they may be able to design cues into the VE from which users will form perceived physical characteristics, and these characteristics may in turn enable the realization of affordances.

**Affordances depend on the organism's sources of sensory stimuli**. This principle asserts that different senses result in different affordances. As developed in the conceptual model, the applicability of this principle in VEs was particularly at risk, as VEs in their present form are impoverished in multiple sensory modalities. Indeed, the entire experimental design was developed as a method to test hypotheses that substitution of sensory stimuli in present modalities could enable realization of affordances that in reality require stimuli in modalities which are impoverished in virtual environments. The discussion of the results against the formulated hypotheses demonstrated that for the conditions tested, it is possible to provide substitution stimuli, thereby enabling the realization of specific affordances. The implication for designers is that they may be able to substitute stimuli in visual and auditory modalities for impoverished modalities.

**Affordances depend on integration of multimodal sensory stimuli**. Gibson (1979) Van Der Steen (1996), Wertheim (1994) and Marik (1987) all demonstrated that perception in reality depends on integration of multimodal stimuli. This principle was at risk in VEs, again because VEs in their present form lack sensory modalities essential for realization of important affordances. The present research proposed and the results demonstrate that this deficiency can be overcome by substituting sensory stimuli in present modalities for absent modalities, for example, presenting a visual cue of shoulder width for the missing kinesthetic modality. The conceptual model argued that visual cues should be appropriate to enable realization of affordances which are primarily spatial, and a combination of visual-auditory cues would prove best for affordances which are primarily temporal. As discussed in regards to the catchability hypothesis, the evidence developed in the present research supporting auditory cues for temporal affordances is weak, but this may well be a limitation of the conditions considered. The implication is that designers may be able to exploit the types of cross-modal interactions that transpire during direct perception in the real world by leveraging sensory substitution schemes that can be enacted when a critical sense cannot be represented in a virtual world.

**Affordances arise as the organism learns to act within its environment**. This last principle was not particularly at risk, as the literature demonstrates that users can learn to operate virtual environments (Card et al. 1983; Anders, 1999). The present research exploited this principle by employing a "training room" during the initial moments of each participant's exposure. Participants were encouraged to remain in the training environment to experiment with the possible behaviors as long as desired. The low error rates observed (flying when rotating was meant, and so forth) indicate that participants did in fact learn to act appropriately within the virtual environment.

## Implications of Interface Display Type

The effectiveness of design artifacts intended to enable the realization of affordances could depend on interface display type. Two affordances (passability and catchability) showed a significant difference between the HMD and Screen displays. In contrast, there was no significant difference between the HMD and screen for the flyability affordance. In regards to passability, participants were somewhat more likely to rotate with the HMD than with the screen. In regards to catchability, participants were somewhat more likely to judge the ball shot as catchable with the HMD as compared to the screen. Since the affordances finding media significant are those that exist in the real world as contrasted with the one that failed to achieve significance (i.e., flyability), it is possible that participants found the HMD a more "real" or immersive experience than the screen. Within this interpretation, the media would not have affected flyability as much because flying as implemented in this VE is an inherently unreal experience. Some participant comments received on the Cue Perception Questionnaire support this interpretation because participants' actions, regardless of display type were that they: "flew whenever I could"; "flew because it was fun." The implication is that it may be advantageous to incorporate immersive displays to enhance the realization of real-world as opposed to supernatural affordances.

## Implications for Virtual Environment Applications

Techniques for enabling the realization of specific affordances in specific circumstances have significant implications for VE applications. The Background chapter developed an argument that the three affordances tested in the present research represent three fundamental kinds of interaction that repeatedly and regularly arise in VE designs: interactions with static elements (passability), interactions with dynamic elements (catchability); and interactions not possible in the real world (flyability). The correct realization of these affordances affects the usability and usefulness of VE applications. For example, a VE implementing an aircraft maintenance trainer requires an accurate realization of passability to ensure that the user will experience the same limitations on access as they will on the real aircraft. A VE interface implementing tools for air traffic controllers, particularly military air traffic controllers, requires an accurate realization of catchability to ensure that the closure rates of different aircraft are correctly understood by the operator. Finally, an interface implementing a VE for data mining, in which a user might virtually fly over and through data, would require an accurate realization of flyability, so that users consistently notice significant datum.

## Implications for the Design of Virtual Environments

Table 26 provides a summary of the various preliminary guidelines for the design of VE interfaces that result from the discussion of the experimental results. The guidelines may be classified as either confirming expectations based on current literature on real world affordance realization, or defining a novel contribution to the literature based on the results of the current study.  Future research should focus on further validating these guidelines.

Table 26:  Preliminary design guidelines for realizing affordances in virtual environments.

| **Affordance** | **Factor** | **Guidelines** | **Contribution** |
|---|---|---|---|
| Passability | Evoking Circumstances | Provide objects with vertical gaps and edges | Confirms real world affordance behavior |
| | Physical Characteristics | Provide visual cues as to self-shoulder width when gaps approach the critical ratio of 1.3 passage width to 1.0 shoulder width | Novel contribution of the present research - visual cues can replace missing proprioceptive shoulder cues |
| | Action Capabilities | Provide capability to rotate | Confirms real world affordance behavior |
| Catchability | Evoking Circumstances | Provide objects that indicate detectable height and speed | Confirms real world affordance behavior |
| | Physical Characteristics | Provide visual and audio cues that indicate self-acceleration and self-speed when objects to catch will land near the critical ratio of 1.2 times the actual catch range | Novel contribution of the present research - visual and auditory cues can replace missing proprioceptive self-acceleration and self-speed cues |
| | Action Capabilities | Provide capability to move | Confirms real world affordance behavior |
| Flyability | Evoking Circumstances | Provide objects with vertical and horizontal edges and gaps | Confirms real world affordance behavior |
| | Physical Characteristics | Provide visual cues that indicate self-height when object to fly over approaches the critical ratio of ½ of the eye point height, and width when the gap to fly through approaches the critical ratio 2.5 gap width to 1.0 shoulder width | Novel contributions of the present research.- 1) identified critical invariant ratios relating body characteristics to action capabilities available only in the VE and 2) visual cues can replace missing proprioceptive cues required for enabling realization of affordances related to action capabilities. available only in the virtual environment |
| | Action Capabilities | Provide capability to fly | Confirms real world affordance behavior |

# CHAPTER 6: CONCLUSIONS AND FUTURE RESEARCH

## Summary of the Present Research

Virtual Environment interface designs are unique because they aim to present a virtual world, in which users may experience a strong sensation that they are immersed in, or part of, a computer generated world. This "immersiveness," while generally more engaging and vibrant than conventional HCI approaches, brings with it unique design issues. Specifically, VEs aim to present dynamic, multimodal interactions with their represented environment just as the natural environment does. Existing HCI design principles have largely focused on static representations and thus have yet to fully incorporate theories of perception appropriate for the dynamic multimodal interactions inherent to VE interaction. This has led to VE designs whose usability are less than desired, likely because their users cannot readily perceive actions and functions that can and should be enacted. There is thus a need to integrate a comprehensive theory of perception into VE design. Theories of direct perception, in particular affordance theory, may prove particularly relevant to VE system design because affordance theory provides an explanation of the interaction of an organism with its environment. Since VEs intrinsically present an environment, examining how an individual interacts with their surroundings when using a VE should prove particularly interesting and informative. Virtual environment design based on affordance theory could help bridge the gap between what HCI theories provide and VE design needs because affordances purport to explain the communication between objects and observers of an environment. The present research constructs a model of how affordances are realized in the natural world, and how lack of sensory stimuli may lead to realization failures in virtual environments. Specifically, VEs may lack stimulation of human senses such as vestibular or kinesthetic, and stimuli from the natural world, which are uncorrelated with the intended virtual experience, may intrude and be perceived by the user. The present research proposes that missing sensory stimuli may be successfully replaced by substituted stimuli in modalities actually present, leading to correct perception of affordances.

The present research synthesized from the affordances literature and predicted on the model a set of principles enabling the realization of affordances:

- Affordances depend on objects in the environment.
- Affordances depend on the organism's action capabilities.
- Affordances depend on physical characteristics of the observer.
- Affordances depend on the organism's sources of sensory stimuli.
- Affordances depend on integration of multimodal sensory stimuli.
- Affordances arise as the organism learns to act within its environment.

The model and these principles formed an assertion that could be investigated and from which testable hypotheses could be derived. The research investigated implications of the model and these assertions by considering three affordances: passability, catchability, and flyability. Passability in the real world is indicated by the tendency to rotate when approaching a gap or passageway relatively close to shoulder width. Passability is important because it is fundamental to interaction with static objects in an environment, and as such it directly addresses issues of spatial perception in a virtual environment. Catchability in the real world is the judgment by observers that a moving object can be intercepted in flight. Catchability is important because it is fundamental to interaction with dynamic objects in an environment, and as such catchability involves a temporal component unlike passability, which must be investigated in terms of its realizability in virtual environments. In contrast to passability and catchability, flyability is not a real world affordance. It is the decision to fly in a given set of circumstances as opposed to selecting other forms of locomotion. Flyability is important because it is a fundamental action not available in reality, which VE designers may like to provide to their users, and as such tests the ability of the model to predict how VE users will experience and choose new or unusual capabilities.

The research formulated a set of testable hypotheses based on the conceptual model developed relating to what information would be necessary in the VE to enable the realization of these affordances and how that information could be delivered in the absence of necessary sensory modalities such as vestibular and kinesthetic senses. The research tested the hypotheses through an extensive experimental program. The experimental design involved four factors for each of the three affordances and was implemented as a $2_{IV}^{4-1}$ fractional factorial design. The four factors related to passability considered were: three visual cues for shoulder width (cueing for physical characteristics) and one cue for passageway width (cueing for object properties). The four factors related to catchability considered were: two visual cues and one audio cue for range (cueing for physical characteristics) and one cue for the object to be caught (cueing for object properties). The four factors related to flyability considered were: two visual cues for size (cueing for physical characteristics) and two cues for window size (cueing for object properties). The experimental apparatus consisted of a series of large rooms implemented in a virtual environment. The cues related to a given affordance were presented in each room as controlled by the experimental design.

The results demonstrated that, as predicted, in the absence of cueing information (i.e., for conventionally designed VEs), the affordances considered were not realized. The predictions for passability and catchability were predicted on existing research, whereas the prediction for flyability was extrapolated from passability and argument. The results demonstrated that for each of the affordances considered when the designed cues for physical characteristics and object properties were provided it led to behavior closely in-line with predicted values. More specifically, when given affording cues participants tended to rotate their virtual bodies when entering narrow passageways, accurately judge balls as catchable, and fly when conditions warranted it. The results provide a set of preliminary guidelines for VE designers to enable the realization of affordances, which should be further validated through future research.

## **Findings of the Present Research**

The present research has demonstrated three essential findings with explanatory power for enabling the correct perception of affordances in virtual environments.

First, the present research has demonstrated that designed sensory stimuli in available sensory modalities substituted for absent or impoverished modalities in a VE may enable the perception of affordances in VEs with a result comparable to perception of the same affordances in reality. The research has provided potential approaches for designing stimuli; however, the conceptual model and results developed may be criticized as not completely addressing how sensory stimuli are actually processed in the brain. This focus on design of stimuli is herein suggested to be an appropriate approach for the design of virtual environments. First, the only means VE designers have to communicate with users is through design artifacts which become the stimuli in the virtual environment. Second, focusing on design is also fully consistent with the focus of other research in ecological perception. Stoffregen and Riccio (1988) for example argue that the ecological approach to understanding perception is a "black box," where the focus is on the stimuli not on the processing of the stimuli. Future research in this light should focus on substituting sensory stimuli for absent modalities and for affordances not tested in the present study.

Second, the present research has demonstrated potential approaches for enabling the perception of affordances in a VE, which in the real world are cross-modal. The present research focused on cross-modal perception for two reasons. First, circumstances requiring cross-modal perception have been shown to lead to incorrect perception (Stappers, 1999), and second, most perceptions are in fact cross-modal. Stoffregen and Riccio (1988) state that a great deal of information is only conveyed via cross-modal stimulation, such as that required to walk, sit, and so forth. Future research in this light should focus on confirming the matching of visual stimuli for a wider range of spatial affordances, and on confirming the matching of combined visual/audio stimuli for temporal affordances.

Third, the present research has demonstrated that affordances relating to action capabilities may be enabled by designed sensory stimuli. The criticism may be raised that affordances besides those related to action capabilities are of interest, for example affordances associated with abstract information. However this focus is appropriate for an approach grounded in ecological perception. Flach and Holden (1998) for example describe Gibson (1986) as choosing constraints on action as the fundamental basis for the reality of experience. The conceptual model of the presence research distinguishes between action capability, that is, actions which an organism can attempt, and the limitations of the environment, either real or imagined, that create constraints. Flach and Holden (1998) state "the implication of Gibson's approach for virtual reality is a focus on the coupling between perception and action as the focal point of design." Future research in this light should focus on developing a design approach that integrates cues for multiple affordances.

## Future Research

One measure of the value of a research effort is the avenues of pursuit for additional research it opens. The following discussion explores some future research that the present work invites.

The first step would be to confirm the results of this study by testing sensory substitution schemes based on the same approach given the same affordances as well as different affordances. Turvey et al. (1998), for example, argues that objects afford their heaviness to observers. This affordance would clearly depend on action capabilities in the real world (arm strength), which are not accurately reflected in a virtual environment. The research issues would be "can such an affordance be realized in a virtual environment?", and if so, "what cues enable its realization?" In parallel with this line of investigation, the results of the experiments such studies should be analyzed against the results of the Immersive Tendencies Questionnaire (Witmer & Singer, 1996) and the Motion History Questionnaire (Kennedy & McCauley, 1984), to discover if affordances are enabled and realized differently by identifiable sub-groups of respondents.

The line of future research most complementary to the present research would be to investigate the possibilities offered by the sixth principle synthesized for enabling affordances: "Affordances arise as the organism learns to act within its environment." Marik 1987's experiment suggests that physical characteristics have persistence in the stimulus integration mechanism, and do not simply arise from sensory stimuli. One implication of this, not pursued in the present research, is that a VE could present cueing early in a VE session, which might persist through the experience. In other words, early cueing might eliminate the need for continued cueing.

Another line of inquiry building on the present research would be to consider circumstances that offer multiple affordances simultaneously. Within the sensory substitution scheme adopted here, this would require integrating cues that enable multiple affordances. The failure of the form cue to significantly enable the passability affordance suggests that there may be difficulties with integrating cues may not succeed. The form cue essentially is the bar cue with a neck and simple head mounted on top of it, which apparently confounded the affordance that was present with the simple bar. It is unclear whether the presence of the neck and head afforded something besides passability, or provided a mis-affordance (i.e., contraindication of passability), or simply cluttered the scene too much for the participant to integrate the correct perception. The issue that arises is how users would be able to integrate many cues in the scene, to enable the realization of a range of affordances.

A desirable research goal in ecological perception is to create a scheme by which the cues enabling perception of any affordance could be realized. The present research has not attempted this, instead focusing on the enabling of three representative affordances. The three affordances selected, passability, catchability, and flyability, are important because they address fundamental functions associated with successful operations in any environment. Furthermore, they deal with three general cases of interest; interaction with static objects in the environment (passability), interaction with dynamic objects in the environment (catchability), and exercise of action capabilities not present in the real world (flyability). Toward a more general scheme for enabling the perception of affordances, the enabling of additional specific affordances that have been documented in the literature could be pursued. Warren's (1984) study, which found phase transition points between walking up stairs and climbing up them on all fours, is another opportunity that could capitalize on the approach adopted in the present research. Likewise Marik's (1987) finding that the affordances of "climb-ability" and "sit-ability" are expressed as constant proportions of leg length suggests that they, like the affordances herein studied, may depend on cross-modal perception and could likewise benefit from this approach. Such studies should confirm that the affordances (heaviness, walk-ability, climb-ability, and sit-ability) are not correctly perceived in ordinary virtual environments, but that additional visual and/or auditory stimuli can enable their correct perception.

The conceptual model for the present research, as captured in Figure 4, was constructed from a synthesis of existing literature on perception of affordances (Marik, 1987; Warren, 1984; Warren & Whang, 1987). This model suggests that affordances are invariantly scaled to physical characteristics and that the sources of such information are missing or impoverished in virtual environments. The present research focuses on providing stimuli that substitute for missing or impoverished stimuli.

Consideration of the conceptual model in Figure 4 raises issues beyond sources of stimuli and knowledge of physical characteristics and action capabilities as addressed in the present research. Specifically, the conceptual model asserts that an organism's internal goals and motivation also contribute to enabling the realization of an affordance. The present research does not address the exploitation of knowledge about goals or motivations in enabling the realization of affordances, but imposed a motivation by exploiting a game motif in the instructions to the participants. Future research could investigate how such knowledge is acquired and exploited, and how an organism's behavior regarding such stimuli may provide indication of their goals. For example, Readinger, Chatziastros, Cunningham, Bülthoff, and Cutting (2002) suggest that there may be an invariant relating gaze and direction of travel. Since gaze, unlike shoulder width for example, is a body characteristic that the human controls, if it is invariantly related to behavior (such as the goal or motivation to choose direction of travel), that would suggest a new line of research building on the present work that would reveal knowledge about action capabilities and goals or motivations. This may provide insights on what the human would like afforded at the moment based on their goals and motivation, and could lead to VE interface designs that adapt to their user's desires.

The concept of affordances is so immediately accessible and so plastic that many researchers would like to extend the paradigm beyond perception of reality. De Angeli, Romary, and Wolff (1999), for example, argue that the affordances paradigm can be extended to explain variations in gestures, thereby forming the basis of HCI based on communication by gestures. Since the perception of gestures would involve the perception of one's own gestures through the tactile senses, the present research may offer insights into this pursuit.

Not directly related to developing affordances as a practical VE design technique, the present research has raised questions about the possible utility of HMD versus Screen presentations, which would also provide a fruitful line of research.  Issues such as stereoscopic displays, resolution of displays, and style variants related to presentation media could be investigated.

# APPENDIX A: AFFORDANCES IN VIRTUAL ENVIRONMENTS PROTOCOL

**<u>Instructions to experimenter</u>**

This protocol is written as instructions to the experimenter, but includes all instructions to participants.

## 1. Informed Consent

Basic English language proficiency is required for the informed consent process. If there is any indication that a participant is not English proficient, explore whether or not they do though casual conversation. If you believe that a participant does not have basic English skills, terminate the experiment, and tell the participant that the experiment is complete, and invite them to leave.

Say: "This experiment will involve your exposure to a virtual environment, that is an environment which is created in a computer, and in which you can participate by wearing a head mounted display or viewing a projection screen, and using a computer mouse.

There are risks associated with this experiment. You may experience nausea, vomiting, eyestrain, or dizziness. The risks associated with participation are no greater than those associated with playing any immersive interactive video game or riding an amusement park ride. You can and should terminate the experiment if your discomfort becomes too great. The Institutional Review Board of The Boeing Company has approved this project. An Institutional Review Board approves experiments involving humans when it believes that the risk to the participants is proportional to the possible scientific merit.

This form (show them the informed consent form) explains in detail the risks of this experiment to you, and your rights regarding your participation in this experiment. Please read this carefully. If you choose not to sign, we will dismiss you from the experiment with no consequences to you. If you choose to sign, we will give you a copy of the form for your records.

Wait for their review of the form and consent by signature. Answer any questions they have as fully as possible. If they decide not to sign the form, please ask them politely to leave (consent is required for participation).

## 2. Pre-exposure Screening

### 2.1. Simulator Sickness Questionnaire (attached, score of 7.48 or below is required to proceed)

Say: "Please complete this Simulator Sickness Questionnaire, which tells us how you feel today. This data will not be shown with your name to anyone outside of the experimental program. You have the right to refuse to answer any question for any reason."

Do not tell them that a high score will terminate the experiment. When complete, score. They must get a score of 7.48 or below to continue (more than 2 slights or one moderate). If they do not, please ask them politely to leave (satisfactory physical condition is required for participation).

Retain form for additional SSQ scores after exposure in the Virtual Environment.

## 3. Pre-exposure Baseline Information

If any time, the participant expresses a reluctance to provide information requested on these questionnaires, offer politely to terminate the experiment without prejudice.

### 3.1. Create Record

Record the participants name on the signed informed disclosure. Enter the participant's number on all surveys. If asked, explain what the number is for, and the protections that will be accorded it.

### 3.2. Demographics Information (attached)

Say: "Please complete this Demographics Information sheet, which tells us about you. This data will not be shown with your name to anyone outside of the experimental program. You have the right to refuse to answer any question for any reason."

Retain the form when completed.

### 3.3. Immersive Tendencies Questionnaire (attached)

Say: "Please complete this Immersive Tendencies Questionnaire, which tells us how likely you are to immerse yourself in artificial experiences. This data will not be shown with your name to anyone outside of the experimental program. You have the right to refuse to answer any question for any reason."

Retain the form when completed.

### 3.4. Motion History Questionnaire (attached)

Say: "Please complete this Motion History Questionnaire, which tells us how much experience you have had with various kinds of unnatural motion. This data will not be shown with your name to anyone outside of the experimental program. You have the right to refuse to answer any question for any reason."

Retain the form when completed.

## 4. Virtual Environment Orientation

### 4.1. Accommodation to head mounted display

Say: "Now we're ready to brief you on your exposure to the virtual environment. During exposure, you'll wear this head mounted display (HMD) so it can provide you with visual information about the virtual environment."

Show the participant the HMD and let her or her handle it. Answer any questions.

### 4.2. Use of computer mouse

During the discussion, Stand and illustrate the explanation of the mouse and movement with your body.

Say: "in order to move about the VE you will use the mouse. If you roll it forward, you will move forward. If you roll it back, you will move back. The further you move it, the faster you go. The left mouse button controls your body rotation. If you click and hold the left button, you will rotate your body to the left; if you release the left button you will return to facing forward. You are limited to a 90-degree rotation. Body rotation does not effect the direction you are facing, or the direction you are traveling. The right mouse button controls your attitude. If you click and hold the right mouse button, you will rise off the ground. If you release the right button, you will return to the earth. You are limited to a height of 2.5 meters off the ground. Flying does not effect the direction you are facing, or the direction you are traveling."

Show the participants the mouse and let them handle it. Answer any questions.

### 4.3. Tasks to perform in environment

Point to each piece of equipment when named in the explanation.

Say: "The virtual environment you will be experiencing is a prototype of a game, not a complete game. The game involves traveling through virtual rooms and interacting with a virtual ball. We are using this environment to investigate how people perceive information presented in the environment. Do not concern yourself about what information we are investigating, just behave as seems fitting to you.

During your exposure to the virtual world, in the real or physical world, you will remain seated at this desk, looking through the head mounted display or at the projector screen as instructed, and manipulating the mouse. Of course, you can choose to stop the experiment at any time for any reason.

All of the following description is about the virtual world.

During your exposure, you will experience one of three different scenarios in each virtual room. The scenarios are repeated in random order and with slightly varying details. The rooms will be like those in an ordinary large building, 3 meters high, five meters wide, and twenty meters long (9 x 15 x 60 feet) – a large narrow room. When you enter each room, you will see a post or podium in the room, which exists to help keep you oriented. Your overall task is to go through the environment, moving from post to post to post. The post is triangularly shaped, and the higher corner indicates the direction you should go. When you "walk over" the post, the virtual environment will sound a "ding" and briefly "freeze" your position. While you are frozen, the post will sink into the floor. When you leave the room, the post will appear in the next room. There is only one post at any time, so if you see it, it's the right one.

In the first scenario, you will be facing a wall through which is a single passageway exiting the room. Your task is to walk over the post, and then exit the room. As some passageways will be narrow, you may decide you should rotate your virtual body to slip through easily. Use the left mouse button to rotate if you think it appropriate to rotate.

In the second scenario, you will be in a room facing a wall with two exit passageways, and with a ball-throwing machine in the floor near the exits. After you walk over the post, a ball will be tossed at you in such a way as to land in front of or behind you. Your task is to judge whether or not you could have gotten to the ball before it lands in order to catch it. This is not a judgment as to whether or not you have sufficient dexterity to catch it, just a judgment as to whether or not you could have positioned yourself to catch it before it touches the floor. If you like, you can start "moving" so as to catch the ball to improve your judgment. You record your judgment by exiting through the green (left) passageway if you think you could have caught the ball on the fly, or the red (right) passageway if you think you could not have caught it in the air. That's green-left if 'yes', and red-right if 'no'.

In the third scenario, you will be standing in a virtual room, facing a wall through which is a passageway and a window. Your task is to walk over the post and exit the room. To do so, you may decide to walk out the passageway or fly out of the window at your own discretion. Do that which is easiest. Use the right mouse button to fly if you think it appropriate to fly.

If at any time during the exposure, you want to terminate the experiment, simply tell me.

If at any time during the exposure, you are unsure what you are being asked to do, simply ask me.

This is not a time trial. You cannot make any mistakes.

Do you have any questions?" Answer any questions.

•

## 5. Virtual Environment Exposure

### 5.1. Entry into environment

Seat the participant and let him or her adjust the chair for comfort. Give him or her the mouse. Help him or her don the helmet.

### 5.2. Task Procedure

Start the virtual environment at 800x600x 16 (full screen). Note the participant's number on the survey forms. Monitor the participant's appearance and terminate the experiment if the participant appears ill. Answer any questions raised, and note the questions.

The first room is a training room. Here first help the participant learn to control speed and direction. Then explain the prompting human form used only this is room. Then have the participant use the body rotation and fly mouse buttons. Then have the participant walk over the first post and watch the ball throw. Then have the participant fly over the half-height walls. Then have the participant rotate through the columns. Restart the environment if the participant gets confused or exits the training room. Spend as much time as required for the participant to be comfortable with control movement and position before proceeding. Let them decide when to proceed.

In the passability rooms (single exit), prompt the participant by saying “your task here is to simply to exit cleanly, rotate if you think it would be easier to do so”.

In the catchability rooms (two exits, one green, one red), prompt the participant by saying: “Your task here is to judge whether you could have gotten to the ball before it hits the ground to catch it. If you think yes, exit left; if not, exit right.”

In the flyability rooms (two exits, one door, one window), prompt the participant by saying “your task is to exit either thru the door or the window, do whichever is easiest”.

Monitor the participant for discomfort and terminate the experiment if their discomfort is too great.

## 6. Post-exposure Tests

### 6.1. SSQ questionnaires

See paragraph 2.2 and do the same after each exposure, once for the HMD, and once for the projector.

### 6.2. Cue Survey

Say: “Please complete this Cue Perception Questionnaire, which tells us how much the you notices the cues present, and what you thought their effect was. This data will not be shown with your name to anyone outside of the experimental program. You have the right to refuse to answer any question for any reason.”

Retain the form when completed.

Say: “Thank you, the experiment is complete, you can leave if you feel well.” If they do not feel well, or their SSQ is significantly above 7.48, ask them to wait 15 minutes in the quiet room.

## 7. Record Results

Encourage the participant to remain in the lab if they are continuing to experience any unpleasant side effects (nausea, dizziness, etc).

Gather all the paperwork associated with the participant and place in an envelope labeled with the participant’s number, and file the envelope in a locked cabinet.

If the experiment is terminated early, change, change their participant number to XX-C, where XX is the original participant number, and “C” is a code indicating the reason for termination:

E -> early exit by participant
X -> experimenter error
C-> computer problem
O -> Other

Rename the results file to “resultsXX.txt”, where XX is the participant’s number.

## Affordances in Virtual Environments – Informed Consent

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

Purpose of the research study: The purpose of this study is to examine how you perceive information presented in virtual environments and how exposure to such environments affects your perception. The results may be used to develop design guidelines for user interfaces.

What you will be asked to do in the study: You will be asked to complete a series baseline tests about your perception and questionnaires describing your general physical condition and prior experience in virtual environments. You will then be asked to wear a helmet-mounted display and use a light hand control. You will be given a short orientation to the virtual environment. The virtual environment consists of rooms like those in an ordinary large building, typically, 3 meters high, five meters wide, and fifteen meters long. You will be asked to attempt a series of simple tasks such as pursuing a ball in the virtual environment. At the conclusion of the tasks, you will be asked to complete a series of tests to assess your re-accommodation to reality.

Time required: One (1) hour or less.

Risks: You may experience nausea, vomiting, eyestrain, or dizziness. These risks are no greater than those associated with playing any immersive interactive video game or riding an amusement park ride. You should terminate the experiment if your discomfort becomes too great. The Institutional Review Board at The Boeing Company has approved this project.

Benefits / Compensation: There is no direct benefit to you for participation. Your time spent on this project is uncompensated and may not be charged to any Boeing project. Your copy of this signed consent form is proof that you have participated.

Confidentiality: Your identity will be kept confidential to the extent provided by law. Your data will be assigned a code number. The list connecting your name to this number will be kept in a locked file in the faculty supervisor's office. The list will be destroyed when the study is completed and the data have been analyzed. Your name will not be used in any report.

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

Right to withdraw from the study: You will be free to withdraw from the study at any time. There are no hazards or penalties from withdrawing from the study.

Whom to contact if you have questions about the study: The Principal Investigator is David Gross, Associate Technical Fellow, Modeling & Simulation Technology, Phantom Works, (256) 461-3294. The Supervisor is Mr. Bill Tucker, Manager, Modeling & Simulation Technology, Phantom Works, (256) 461-3120.

Payment of Medical Costs. If you are injured during this test, Workers' Compensation will cover your medical costs and applicable time loss. Other Boeing benefit programs you are enrolled in at the time of the test will apply as well.

Your rights in the study: Additional information regarding your rights as a research volunteer may be obtained from:

J. Michael Muhm
Institutional Review Board (IRB) The Boeing Company
M/S 7A-XH
PO Box 3707
Seattle, WA 98142-2207
mike.muhm@boeing.com Telephone: ( 425)865-6631

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

I have read the above information and understand the participation in this research project is voluntary. Refusal to participate, or a decision not to continue to participate, will involve no penalty or loss of benefit to which I am otherwise entitled.

Participant: ______________________________ Date: ____________________ Participant Number: _____
Investigator: _____________________________ Date: _________________

## Affordances in Virtual Environments – Demographics Information

1) What is your age? _____ years

2) What is your gender ? MALE FEMALE

3) What is your height? _____feet ____ inches

4) Are you color blind ? NO YES If so, what type? ________________________

5) Is there any reason you can not work around TV/Radio signals?
NO YES If so, Why? ________________________________________________

6) Do you have normal vision?
NO YES If so, skip to question 8

7) Is your vision corrected by …
GLASSES CONTACTS NOT-CORRECTED

8) If corrected, are you using it now ?
YES NO If not, why not? _____________________________________

9) Do you have any other unusual vision conditions?
NO YES If so, what? __________

10) Do you have normal hearing? NO YES If so, skip to question 14

11) Is your hearing … CORRECTED NOT-CORRECTED

12) Are you wearing your hearing correction?
YES NO If not, why not? _____________________________________

13) Do you have any other unusual hearing conditions?
NO YES If so, what? _________________________________________

**14) I am [ RIGHT | LEFT | AMBIDEXTROUS ] handed (circle one).**

**Affordances in Virtual Environments – Cue Perception Questionnaire**

The virtual rooms presented three scenarios. Each scenario was repeated a number of times, with slightly varying details, or cues. This survey is to discover what you remember about the cues and how you think that they affected your behavior in the environment. Please complete the following tables.

Passability -- room with single passageway exit

Why did you decide you should rotate, if you did? ___________________________
_____________________________________________________________________

| Cues Noticed | Perceived Effect |
|---|---|
| | |
| | |
| | |
| | |

Catchability -- room with two passageway exits, and ball thrown

Why did you decide you could catch it, if you did? __________________________
_____________________________________________________________________

| Cues Noticed | Perceived Effect |
|---|---|
| | |
| | |
| | |
| | |

Flyability – rooms with single passageway and single window exits

Why did you decide you should fly, if you did? _____________________________
_____________________________________________________________________

| Cues Noticed | Perceived Effect |
|---|---|
| | |
| | |
| | |
| | |

# APPENDIX B: ANALYSIS OF PARTICIPANT SURVEY RESPONSES

Participants were asked to complete version 3.01 of the Immersive Tendencies Questionnaire (Witmer & Singer, 1996)

.In general, the higher the answer, the more likely is a participant to suspend disbelief and immerse himself in the experience. Figure B-1 shows the mean response for each participant group with error bars indicating the 95% confidence intervals. By inspection, it can be sent that the confidence intervals overlap, which indicates that no statistically significant difference was found with regard to these factors between the various participant groups.

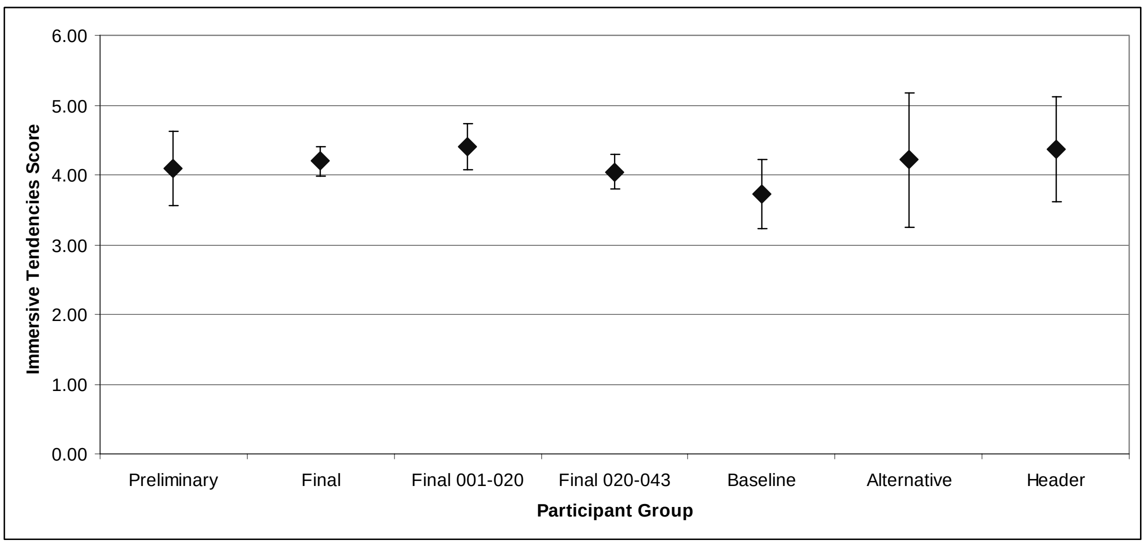


Figure B-1: Immersive tendencies questionnaire average response per group.

Participants were asked to complete a Motion History Questionnaire developed by Kennedy and McCauley (1984). Three questions are particularly revealing about the likelihood that a participant would experience simulator sickness in the VE: "2) How often would you say you get airsick?"; "4) From your experience at sea, how often would you say you get seasick?"; and "7) In general, how susceptible to motion sickness are you?" The first two questions provide responses: Always, Frequently, Sometimes, Rarely, and Never; the last provides: Extremely, Very, Moderately, Minimally, and Not at all. To better support analysis, the participant's responses were converted into numbers one through five, where one was assigned to the first response and five was assigned to the last. Therefore, higher numerical scores indicate that the participant experienced these symptoms less. Figure B-2 summarizes the results for these three questions for each participant groups with error bars indicating the 95% confidence intervals. By inspection, it can be sent that the confidence intervals overlap, which indicates that no statistically significant difference was found with regard to these factors between the various participant groups.

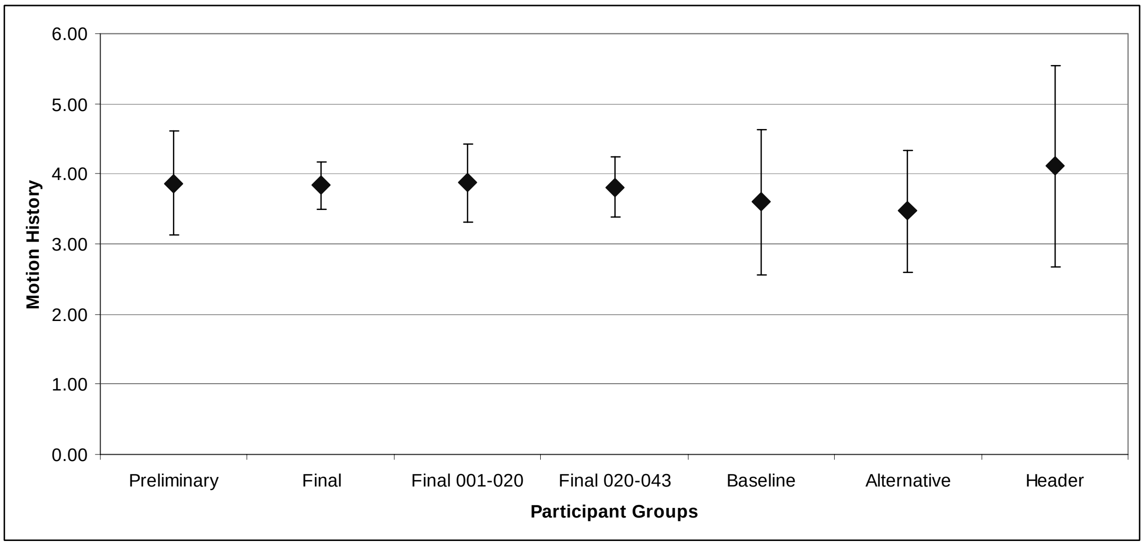


Figure B-2: Motion history average response per group.

Participants completed a Simulator Sickness Questionnaire (SSQ) developed by Kennedy et al. (1993) before any exposure to the VE, after the first exposure, and after the second (as appropriate). As discussed in the Experiment Design, some participants were exposed to the VE first via a HMD, and sometimes first via a computer projector Screen. These reversed in the second exposure. These scores served as a way to judge that a participant was not experiencing too much discomfort to continue the experiment. Any SSQ score above 7.48 resulted in an invitation to terminate the experiment. As noted, five participants chose to terminate. Figure B-3 illustrates the SSQ scores for the final study participant group with error bars indicating the 95% confidence intervals. By inspection, the confidence intervals indicate that there are statistically significant differences between some of the subgroups. The first-exposure-via-HMD subgroup is significantly different that the second-exposure-via Screen. This indicates that the participants recovered from discomfort during their exposure to the Screen. Also, the second-exposure-via-HMD subgroup is significantly different than the second-exposure-via-screen. This indicates that the HMD exposure created significantly more discomfort than the Screen exposure.

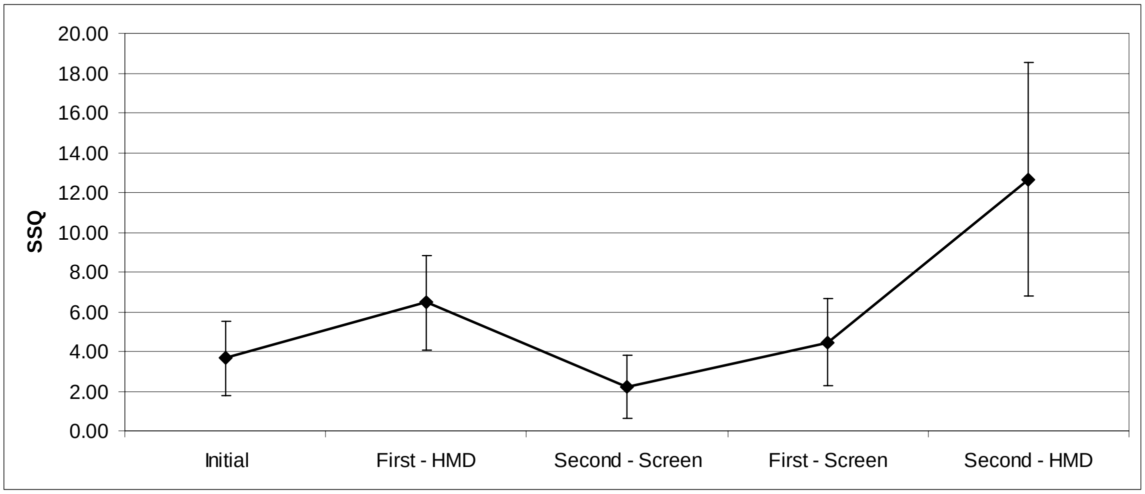


Figure B-3: Simulator sickness scores for the final study participant group.

# APPENDIX C: RESPONSES MEASURED IN THE VIRTUAL ENVIRONMENT

## Example Raw Data – F001-H

| Room | X | Y | Z | Rotate | Speed |
|---|---|---|---|---|---|
| 0 | -4250 | 60 | -100 | 0 | 0 |
| 0 | -4250 | 60 | -100 | 0 | 0 |
| 0 | -4250 | 60 | -100 | 0 | 0 |
| 0 | -4250 | 60 | -100 | 0 | 0 |
| 0 | -4250 | 60 | -100 | 0 | 0 |
| 0 | -4250 | 60 | -100 | 0 | 0 |
| 0 | -4250 | 60 | -100 | 0 | 0 |
| 0 | -4250 | 60 | -100 | 0 | 0 |
| 0 | -4250 | 60 | -100 | 0 | 0 |
| 0 | -4250 | 60 | -100 | 0 | 0 |
| 0 | -4250 | 60 | -100 | 0 | 0 |
| 0 | -4250 | 60 | -100 | 0 | 0 |
| 0 | -4250 | 60 | -100 | 0 | 0 |
| 0 | -4250 | 60 | -100 | 0 | 0 |
| 0 | -4249.273 | 60 | -100.7161 | 0 | 60.000004 |
| 0 | -4248.59 | 60 | -101.3902 | 0 | 60.000004 |
| 0 | -4247.864 | 60 | -102.1064 | 0 | 60.000004 |
| 0 | -4247.18 | 60 | -102.7805 | 0 | 60.000004 |
| 0 | -4246.454 | 60 | -103.4967 | 0 | 60.000004 |
| 0 | -4245.77 | 60 | -104.1707 | 0 | 60.000004 |
| 0 | -4245.044 | 60 | -104.8869 | 0 | 60.000004 |
| 0 | -4244.318 | 60 | -105.6031 | 0 | 60.000004 |
| 0 | -4243.635 | 60 | -106.2772 | 0 | 60.000004 |
| 0 | -4242.909 | 60 | -106.9934 | 0 | 60.000004 |
| 0 | -4242.225 | 60 | -107.6674 | 0 | 60.000004 |
| 0 | -4241.499 | 60 | -108.3836 | 0 | 60.000004 |
| 0 | -4240.773 | 60 | -109.0998 | 0 | 60.000004 |
| 0 | -4240.089 | 60 | -109.7739 | 0 | 60.000004 |
| 0 | -4239.363 | 60 | -110.4901 | 0 | 60.000004 |
| 0 | -4238.68 | 60 | -111.1642 | 0 | 60.000004 |
| 0 | -4237.954 | 60 | -111.8803 | 0 | 60.000004 |
| 0 | -4237.228 | 60 | -112.5965 | 0 | 60.000004 |
| 0 | -4236.544 | 60 | -113.2706 | 0 | 60.000004 |
| 0 | -4235.818 | 60 | -113.9868 | 0 | 60.000004 |
| 0 | -4235.134 | 60 | -114.6609 | 0 | 60.000004 |
| 0 | -4234.408 | 60 | -115.3771 | 0 | 60.000004 |
| 0 | -4233.682 | 60 | -116.0933 | 0 | 60.000004 |
| 0 | -4232.999 | 60 | -116.7673 | 0 | 60.000004 |
| 0 | -4232.272 | 60 | -117.4835 | 0 | 60.000004 |
| 0 | -4231.589 | 60 | -118.1576 | 0 | 60.000004 |
| 0 | -4230.863 | 60 | -118.8738 | 0 | 60.000004 |
| 0 | -4230.137 | 60 | -119.59 | 0 | 60.000004 |
| 0 | -4229.453 | 60 | -120.264 | 0 | 60.000004 |
| 0 | -4228.727 | 60 | -120.9802 | 0 | 60.000004 |
| 0 | -4228.043 | 60 | -121.6543 | 0 | 60.000004 |
| 0 | -4227.317 | 60 | -122.3705 | 0 | 60.000004 |
| 0 | -4226.591 | 60 | -123.0867 | 0 | 60.000004 |
| 0 | -4225.908 | 60 | -123.7607 | 0 | 60.000004 |
| 0 | -4225.182 | 60 | -124.4769 | 0 | 60.000004 |
| 0 | -4224.498 | 60 | -125.151 | 0 | 60.000004 |
| 0 | -4223.772 | 60 | -125.8672 | 0 | 60.000004 |
| 0 | -4223.041 | 60 | -126.5783 | 0 | 60.000004 |
| 0 | -4222.352 | 60 | -127.2476 | 0 | 60.000004 |
| 0 | -4221.621 | 60 | -127.9587 | 0 | 60.000004 |
| 0 | -4220.924 | 60 | -128.6265 | 0 | 60.300003 |
| 0 | -4220.185 | 60 | -129.336 | 0 | 60.300003 |
| 0 | -4219.445 | 60 | -130.0455 | 0 | 60.300003 |

| Room | X | Y | Z | Rotate | Speed |
|---|---|---|---|---|---|
| 0 | -4218.749 | 60 | -130.7133 | 0 | 60.300003 |
| 0 | -4218.009 | 60 | -131.4228 | 0 | 60.300003 |
| 0 | -4217.312 | 60 | -132.0906 | 0 | 60.300003 |
| 0 | -4216.573 | 60 | -132.8001 | 0 | 60.300003 |
| 0 | -4215.824 | 60 | -133.5079 | 0 | 60.600002 |
| 0 | -4215.12 | 60 | -134.1741 | 0 | 60.600002 |
| 0 | -4214.371 | 60 | -134.882 | 0 | 60.600002 |
| 0 | -4213.71 | 60 | -135.5065 | 0 | 60.600002 |
| 0 | -4212.962 | 60 | -136.2144 | 0 | 60.600002 |
| 0 | -4212.213 | 60 | -136.9222 | 0 | 60.600002 |
| 0 | -4211.509 | 60 | -137.5884 | 0 | 60.600002 |
| 0 | -4210.76 | 60 | -138.2963 | 0 | 60.600002 |
| 0 | -4210.056 | 60 | -138.9625 | 0 | 60.600002 |
| 0 | -4209.298 | 60 | -139.6685 | 0 | 60.900002 |
| 0 | -4208.541 | 60 | -140.3746 | 0 | 60.900002 |
| 0 | -4207.829 | 60 | -141.0391 | 0 | 60.900002 |
| 0 | -4207.071 | 60 | -141.7452 | 0 | 60.900002 |
| 0 | -4206.341 | 60 | -142.3979 | 0 | 61.200001 |
| 0 | -4205.557 | 60 | -143.0893 | 0 | 61.500004 |
| 0 | -4204.773 | 60 | -143.7807 | 0 | 61.500004 |
| 0 | -4204.03 | 60 | -144.4263 | 0 | 61.500004 |
| 0 | -4203.241 | 60 | -145.1122 | 0 | 61.500004 |
| 0 | -4202.499 | 60 | -145.7577 | 0 | 61.500004 |
| 0 | -4201.709 | 60 | -146.4436 | 0 | 61.500004 |
| 0 | -4200.92 | 60 | -147.1296 | 0 | 61.500004 |
| 0 | -4200.178 | 60 | -147.7751 | 0 | 61.500004 |
| 0 | -4199.389 | 60 | -148.461 | 0 | 61.500004 |
| 0 | -4198.6 | 60 | -149.147 | 0 | 61.500004 |
| 0 | -4197.857 | 60 | -149.7925 | 0 | 61.500004 |
| 0 | -4197.068 | 60 | -150.4784 | 0 | 61.500004 |
| 0 | -4196.325 | 60 | -151.124 | 0 | 61.500004 |
| 0 | -4195.536 | 60 | -151.8099 | 0 | 61.500004 |
| 0 | -4194.747 | 60 | -152.4958 | 0 | 61.500004 |
| 0 | -4194.004 | 60 | -153.1414 | 0 | 61.500004 |
| 0 | -4193.215 | 60 | -153.8273 | 0 | 61.500004 |
| 0 | -4192.473 | 60 | -154.4729 | 0 | 61.500004 |
| 0 | -4191.684 | 60 | -155.1588 | 0 | 61.500004 |
| 0 | -4190.895 | 60 | -155.8447 | 0 | 61.500004 |
| 0 | -4190.152 | 60 | -156.4903 | 0 | 61.500004 |
| 0 | -4189.363 | 60 | -157.1762 | 0 | 61.500004 |
| 0 | -4188.62 | 60 | -157.8218 | 0 | 61.500004 |
| 0 | -4187.831 | 60 | -158.5077 | 0 | 61.500004 |
| 0 | -4187.042 | 60 | -159.1936 | 0 | 61.500004 |
| 0 | -4186.299 | 60 | -159.8392 | 0 | 61.500004 |

… and so forth.

## Task Room 1 Reduced Data

| File | Room | X | Y | Z | Rotate | Speed | RESULT |
|---|---|---|---|---|---|---|---|
| A001-H | 1 | -3071.000 | 60.000 | -81.081 | 90.0 | 57.3 | ROTATE |
| A002-H | 1 | -3071.459 | 60.000 | -80.362 | 90.0 | 43.2 | ROTATE |
| A003-H | 1 | -3071.003 | 60.000 | -84.281 | 0.0 | 55.8 | no |
| A004-H | 1 | -3070.871 | 60.000 | -84.490 | 0.0 | 49.5 | no |
| A005-H | 1 | -3071.133 | 60.000 | -86.811 | 0.0 | 62.7 | no |
| B001-H | 1 | -3070.953 | 60.000 | -114.390 | 0.0 | 14.7 | no |
| B001-S | 1 | -3070.966 | 60.000 | -85.079 | 90.0 | 25.8 | ROTATE |
| B002-H | 1 | -3070.804 | 60.000 | -106.965 | 90.0 | 30.3 | ROTATE |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| B002-S | 1 | -3071.583 | 60.000 | -85.093 | 0.0 | 68.1 | no |
| B003-H | 1 | -3071.153 | 60.000 | -111.164 | 0.0 | 30.0 | no |
| B003-S | 1 | -3070.777 | 60.000 | -82.724 | 0.0 | 54.6 | no |
| B004-H | 1 | -3071.051 | 60.000 | -106.591 | 57.0 | 83.1 | ROTATE |
| B004-S | 1 | -3071.716 | 60.000 | -84.853 | 0.0 | 57.6 | no |
| B005-H | 1 | -3070.907 | 60.000 | -98.701 | 90.0 | 41.4 | ROTATE |
| B005-S | 1 | -3071.610 | 60.000 | -86.005 | 0.0 | 53.4 | no |
| F001-H | 1 | -3070.929 | 60.000 | -91.078 | 0.0 | 13.5 | no |
| F001-S | 1 | -3070.914 | 60.000 | -78.933 | 90.0 | 36.9 | ROTATE |
| F002-H | 1 | -3071.595 | 60.000 | -103.855 | 0.0 | 64.5 | no |
| F002-S | 1 | -3071.627 | 60.000 | -80.926 | 0.0 | 62.7 | no |
| F003-H | 1 | -3071.288 | 60.000 | -95.679 | 90.0 | 40.8 | ROTATE |
| F003-S | 1 | -3071.551 | 60.000 | -83.763 | 0.0 | 147.9 | no |
| F004-H | 1 | -3070.979 | 60.000 | -86.850 | 0.0 | 67.8 | no |
| F004-S | 1 | -3071.042 | 60.000 | -86.530 | 0.0 | 39.3 | no |
| F005-H | 1 | -3071.590 | 60.000 | -91.303 | 0.0 | 52.8 | no |
| F005-S | 1 | -3071.638 | 60.000 | -85.981 | 0.0 | 73.5 | no |
| F006-H | 1 | -3071.252 | 60.000 | -86.845 | 90.0 | 67.5 | ROTATE |
| F006-S | 1 | -3070.774 | 60.000 | -81.888 | 0.0 | 35.7 | no |
| F007-H | 1 | -3071.448 | 60.000 | -95.617 | 90.0 | 48.6 | ROTATE |
| F007-S | 1 | -3070.955 | 60.000 | -86.136 | 0.0 | 88.8 | no |
| F008-H | 1 | -3070.794 | 60.000 | -83.274 | 0.0 | 27.3 | no |
| F008-S | 1 | -3071.135 | 60.000 | -84.745 | 0.0 | 43.5 | no |
| F009-H | 1 | -3071.683 | 60.000 | -96.824 | 90.0 | 60.9 | ROTATE |
| F009-S | 1 | -3072.637 | 60.000 | -78.077 | 0.0 | 150.0 | no |
| F010-H | 1 | -3070.979 | 64.000 | -105.898 | 0.0 | 81.9 | m/b |
| F010-S | 1 | -3070.827 | 60.000 | -82.993 | 0.0 | 29.1 | no |
| F011-H | 1 | -3070.967 | 60.000 | -90.876 | 0.0 | 32.1 | no |
| F011-S | 1 | -3070.868 | 60.000 | -85.696 | 0.0 | 37.8 | no |
| F012-H | 1 | -3071.380 | 60.000 | -82.700 | 0.0 | 72.6 | no |
| F012-S | 1 | -3071.164 | 60.000 | -83.302 | 0.0 | 44.1 | no |
| F013-H | 1 | -3071.164 | 60.000 | -96.101 | 0.0 | 47.4 | no |
| F013-S | 1 | -3072.235 | 60.000 | -78.352 | 0.0 | 111.0 | no |
| F014-H | 1 | -3071.087 | 60.000 | -87.724 | 0.0 | 33.0 | no |
| F014-S | 1 | -3070.876 | 60.000 | -85.890 | 0.0 | 31.5 | no |
| F015-H | 1 | -3071.270 | 60.000 | -89.133 | 0.0 | 36.0 | no |
| F015-S | 1 | -3070.757 | 60.000 | -85.435 | 0.0 | 56.7 | no |
| F016-H | 1 | -3070.902 | 60.000 | -92.297 | 90.0 | 9.9 | ROTATE |
| F016-S | 1 | -3071.418 | 60.000 | -82.256 | 90.0 | 42.9 | ROTATE |
| F017-H | 1 | -3071.216 | 60.000 | -106.410 | 24.0 | 45.0 | ROTATE |
| F017-S | 1 | -3071.329 | 60.000 | -83.809 | 0.0 | 42.9 | no |
| F018-H | 1 | -3071.447 | 60.000 | -96.132 | 0.0 | 54.9 | no |
| F018-S | 1 | -3071.424 | 60.000 | -85.801 | 0.0 | 41.4 | no |
| F019-H | 1 | -3070.948 | 60.000 | -94.199 | 0.0 | 15.6 | no |
| F019-S | 1 | -3071.799 | 60.000 | -84.793 | 0.0 | 93.3 | no |
| F020-H | 1 | -3070.849 | 60.000 | -90.480 | 0.0 | 45.3 | no |
| F020-S | 1 | -3071.068 | 60.000 | -83.115 | 0.0 | 34.5 | no |
| F021-H | 1 | -3071.219 | 60.000 | -93.222 | 0.0 | 34.5 | no |
| F021-S | 1 | -3071.439 | 60.000 | -82.494 | 0.0 | 54.6 | no |
| F022-H | 1 | -3071.064 | 60.000 | -83.019 | 0.0 | 72.9 | no |
| F022-S | 1 | -3071.156 | 60.000 | -85.172 | 0.0 | 51.6 | no |
| F023-H | 1 | -3071.126 | 60.000 | -95.289 | 0.0 | 61.8 | no |
| F023-S | 1 | -3071.422 | 60.000 | -87.706 | 0.0 | 70.2 | no |
| F024-H | 1 | -3070.882 | 60.000 | -100.093 | 90.0 | 50.4 | ROTATE |
| F024-S | 1 | -3070.756 | 60.000 | -87.198 | 0.0 | 43.2 | no |
| F025-H | 1 | -3071.422 | 60.000 | -89.629 | 0.0 | 59.7 | no |
| F025-S | 1 | -3071.686 | 60.000 | -84.150 | 0.0 | 59.4 | no |
| F026-H | 1 | -3071.026 | 60.000 | -83.851 | 0.0 | 57.6 | no |
| F026-S | 1 | -3071.115 | 60.000 | -83.745 | 0.0 | 35.7 | no |
| F027-H | 1 | -3071.439 | 60.000 | -93.707 | 0.0 | 53.4 | no |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| F027-S | 1 | -3070.940 | 60.000 | -84.082 | 0.0 | 89.4 | no |
| F028-H | 1 | -3071.431 | 60.000 | -93.411 | 0.0 | 40.8 | no |
| F028-S | 1 | -3070.808 | 60.000 | -87.282 | 0.0 | 33.6 | no |
| F029-H | 1 | -3071.114 | 60.000 | -87.205 | 0.0 | 46.2 | no |
| F029-S | 1 | -3071.249 | 60.000 | -81.952 | 0.0 | 39.0 | no |
| F030-H | 1 | -3071.118 | 60.000 | -87.484 | 0.0 | 46.8 | no |
| F030-S | 1 | -3071.000 | 60.000 | -87.166 | 0.0 | 37.8 | no |
| F031-H | 1 | -3071.228 | 60.000 | -87.633 | 0.0 | 29.1 | no |
| F031-S | 1 | -3071.768 | 60.000 | -81.260 | 0.0 | 68.7 | no |
| F032-H | 1 | -3070.858 | 60.000 | -95.953 | 90.0 | 59.1 | ROTATE |
| F032-S | 1 | -3071.055 | 60.000 | -84.563 | 0.0 | 44.7 | no |
| F033-H | 1 | -3071.611 | 60.000 | -88.753 | 0.0 | 63.6 | no |
| F033-S | 1 | -3073.043 | 60.000 | -80.069 | 0.0 | 150.0 | no |
| F034-H | 1 | -3071.508 | 60.000 | -108.905 | 0.0 | 76.2 | no |
| F034-S | 1 | -3071.367 | 60.000 | -82.766 | 0.0 | 41.7 | no |
| F035-H | 1 | -3071.206 | 60.000 | -96.182 | 90.0 | 39.6 | ROTATE |
| F035-S | 1 | -3071.345 | 60.000 | -81.319 | 57.0 | 42.3 | ROTATE |
| F036-H | 1 | -3071.063 | 60.000 | -81.062 | 0.0 | 37.2 | no |
| F036-S | 1 | -3071.207 | 60.000 | -80.863 | 90.0 | 35.7 | ROTATE |
| F037-H | 1 | -3070.934 | 60.000 | -98.488 | 0.0 | 60.9 | no |
| F037-S | 1 | -3070.960 | 60.000 | -84.916 | 0.0 | 18.9 | no |
| F038-H | 1 | -3070.760 | 60.000 | -100.955 | 90.0 | 46.5 | ROTATE |
| F038-S | 1 | -3070.983 | 60.000 | -90.925 | 0.0 | 45.0 | no |
| F040-H | 1 | -3070.858 | 60.000 | -86.705 | 0.0 | 38.7 | no |
| F040-S | 1 | -3071.267 | 60.000 | -80.610 | 0.0 | 37.8 | no |
| F041-H | 1 | -3070.859 | 60.000 | -90.254 | 0.0 | 26.4 | no |
| F041-S | 1 | -3071.041 | 60.000 | -86.369 | 0.0 | 65.4 | no |
| F042-H | 1 | -3071.327 | 60.000 | -93.035 | 0.0 | 62.4 | no |
| F042-S | 1 | -3071.447 | 60.000 | -86.713 | 0.0 | 42.3 | no |
| F043-H | 1 | -3070.908 | 60.000 | -94.148 | 66.0 | 34.2 | ROTATE |
| F043-S | 1 | -3071.018 | 60.000 | -87.004 | 0.0 | 24.6 | no |
| H001-H | 1 | -3071.099 | 60.000 | -79.252 | 0.0 | 26.1 | no |
| H002-H | 1 | -3071.072 | 60.000 | -95.445 | 0.0 | 32.7 | no |
| H003-H | 1 | -3071.011 | 60.000 | -94.641 | 90.0 | 36.6 | ROTATE |
| I001-H | 1 | -3071.835 | 60.000 | -95.328 | 0.0 | 68.7 | no |
| I001-S | 1 | -3071.272 | 60.000 | -88.647 | 0.0 | 51.0 | no |
| P001-H | 1 | -3071.425 | 60.000 | -97.754 | 90.0 | 68.7 | ROTATE |
| P001-S | 1 | -3071.498 | 60.000 | -86.164 | 0.0 | 60.3 | no |
| P002-H | 1 | -3071.658 | 60.000 | -104.426 | 90.0 | 68.1 | ROTATE |
| P002-S | 1 | -3070.806 | 60.000 | -84.955 | 0.0 | 22.8 | no |
| P003-H | 1 | -3070.841 | 60.000 | -101.840 | 90.0 | 20.1 | ROTATE |
| P003-S | 1 | -3070.813 | 60.000 | -87.201 | 0.0 | 25.2 | no |
| P004-H | 1 | -3071.060 | 60.000 | -85.176 | 0.0 | 47.1 | no |
| P004-S | 1 | -3072.440 | 136.000 | -90.986 | 0.0 | 101.1 | m/b |
| P005-H | 1 | -3070.908 | 60.000 | -90.168 | 0.0 | 18.9 | no |
| P005-S | 1 | -3070.780 | 60.000 | -81.778 | 90.0 | 21.3 | ROTATE |
| P006-H | 1 | -3071.016 | 60.000 | -79.311 | 0.0 | 58.2 | no |
| P006-S | 1 | -3070.762 | 60.000 | -84.792 | 0.0 | 29.4 | no |
| P007-H | 1 | -3070.808 | 60.000 | -100.563 | 0.0 | 41.7 | no |
| P007-S | 1 | -3070.997 | 60.000 | -84.655 | 0.0 | 17.1 | no |
| P008-H | 1 | -3071.012 | 60.000 | -100.767 | 0.0 | 81.6 | no |
| P008-S | 1 | -3071.069 | 60.000 | -103.670 | 0.0 | 48.3 | no |
| P009-H | 1 | -3070.825 | 60.000 | -86.863 | 0.0 | 40.5 | no |
| P009-S | 1 | -3072.304 | 60.000 | -82.433 | 0.0 | 115.5 | no |
| P010-H | 1 | -3070.788 | 60.000 | -107.432 | 0.0 | 61.2 | no |
| P010-S | 1 | -3071.233 | 60.000 | -105.804 | 0.0 | 38.1 | no |

## Task Room 2 Reduced Data

| File | Room | X | Y | Z | Rotate | Speed | RESULT |
|---|---|---|---|---|---|---|---|

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| A001-H | 2 | -3019.634 | 60.000 | -563.931 | 66.0 | 49.2 | CATCH |
| A002-H | 2 | -2887.812 | 60.000 | -564.464 | 0.0 | 33.6 | not |
| A003-H | 2 | -3007.439 | 60.000 | -564.352 | 0.0 | 28.5 | CATCH |
| A004-H | 2 | -2991.539 | 60.000 | -564.451 | 0.0 | 37.5 | CATCH |
| A005-H | 2 | -2884.837 | 60.000 | -564.261 | 0.0 | 40.2 | not |
| B001-H | 2 | -2981.951 | 60.000 | -564.382 | 0.0 | 17.4 | CATCH |
| B001-S | 2 | -2881.020 | 60.000 | -564.425 | 0.0 | 16.8 | not |
| B002-H | 2 | -2878.880 | 60.000 | -564.279 | 0.0 | 33.0 | not |
| B002-S | 2 | -2876.673 | 60.000 | -564.264 | 0.0 | 58.2 | not |
| B003-H | 2 | -3008.604 | 60.000 | -564.400 | 0.0 | 30.0 | CATCH |
| B003-S | 2 | -2881.942 | 60.000 | -563.992 | 0.0 | 44.7 | not |
| B004-H | 2 | -2995.579 | 60.000 | -563.587 | 0.0 | 58.5 | CATCH |
| B004-S | 2 | -2877.098 | 60.000 | -564.000 | 0.0 | 67.2 | not |
| B005-H | 2 | -2999.796 | 60.000 | -564.185 | 0.0 | 54.6 | CATCH |
| B005-S | 2 | -2882.957 | 60.000 | -564.459 | 0.0 | 9.6 | not |
| F001-H | 2 | -2885.458 | 60.000 | -564.262 | 0.0 | 16.2 | not |
| F001-S | 2 | -2874.737 | 60.000 | -564.018 | 0.0 | 37.5 | not |
| F002-H | 2 | -2884.100 | 60.000 | -564.127 | 0.0 | 68.7 | not |
| F002-S | 2 | -3002.272 | 60.000 | -564.448 | 0.0 | 34.8 | CATCH |
| F003-H | 2 | -2890.297 | 60.000 | -564.103 | 0.0 | 33.9 | not |
| F003-S | 2 | -2995.246 | 60.000 | -563.697 | 0.0 | 87.3 | CATCH |
| F004-H | 2 | -2981.940 | 60.000 | -564.458 | 0.0 | 80.7 | CATCH |
| F004-S | 2 | -2880.810 | 60.000 | -564.275 | 0.0 | 30.3 | not |
| F005-H | 2 | -2879.353 | 60.000 | -564.185 | 0.0 | 33.9 | not |
| F005-S | 2 | -2888.091 | 60.000 | -563.558 | 0.0 | 58.5 | not |
| F006-H | 2 | -3000.766 | 60.000 | -563.711 | 0.0 | 79.5 | CATCH |
| F006-S | 2 | -2877.555 | 60.000 | -564.122 | 0.0 | 61.2 | not |
| F007-H | 2 | -2884.562 | 60.000 | -563.831 | 0.0 | 44.4 | not |
| F007-S | 2 | -2882.359 | 60.000 | -564.356 | 90.0 | 56.4 | not |
| F008-H | 2 | -2887.296 | 60.000 | -564.176 | 0.0 | 42.0 | not |
| F008-S | 2 | -2886.631 | 60.000 | -564.237 | 0.0 | 34.8 | not |
| F009-H | 2 | -2877.375 | 60.000 | -564.312 | 84.0 | 44.1 | not |
| F009-S | 2 | -2874.459 | 60.000 | -562.635 | 48.0 | 135.3 | not |
| F010-H | 2 | -2877.075 | 60.000 | -564.333 | 0.0 | 66.9 | not |
| F010-S | 2 | -2884.455 | 60.000 | -564.007 | 0.0 | 40.8 | not |
| F011-H | 2 | -2887.296 | 60.000 | -564.269 | 0.0 | 26.7 | not |
| F011-S | 2 | -2884.466 | 60.000 | -564.154 | 0.0 | 39.9 | not |
| F012-H | 2 | -2884.323 | 60.000 | -563.594 | 0.0 | 72.0 | not |
| F012-S | 2 | -2885.062 | 60.000 | -564.079 | 0.0 | 27.0 | not |
| F013-H | 2 | -2881.490 | 60.000 | -564.008 | 0.0 | 45.9 | not |
| F013-S | 2 | -2874.495 | 60.000 | -563.190 | 0.0 | 108.3 | not |
| F014-H | 2 | -2887.286 | 60.000 | -564.090 | 0.0 | 41.4 | not |
| F014-S | 2 | -2885.853 | 60.000 | -564.461 | 0.0 | 23.1 | not |
| F015-H | 2 | -2897.524 | 60.000 | -564.080 | 0.0 | 60.0 | not |
| F015-S | 2 | -2875.742 | 60.000 | -564.094 | 0.0 | 62.4 | not |
| F016-H | 2 | -2885.333 | 60.000 | -564.482 | 0.0 | 11.7 | not |
| F016-S | 2 | -2879.488 | 60.000 | -564.380 | 90.0 | 30.6 | not |
| F017-H | 2 | -2882.614 | 60.000 | -563.868 | 0.0 | 40.2 | not |
| F017-S | 2 | -2876.606 | 60.000 | -564.157 | 0.0 | 43.8 | not |
| F018-H | 2 | -2888.114 | 60.000 | -564.098 | 0.0 | 44.4 | not |
| F018-S | 2 | -2883.883 | 60.000 | -564.370 | 0.0 | 23.1 | not |
| F019-H | 2 | -3004.656 | 60.000 | -564.136 | 0.0 | 26.7 | CATCH |
| F019-S | 2 | -2875.900 | 60.000 | -564.053 | 0.0 | 74.1 | not |
| F020-H | 2 | -2892.533 | 60.000 | -564.499 | 0.0 | 49.5 | not |
| F020-S | 2 | -3001.733 | 60.000 | -564.323 | 0.0 | 21.3 | CATCH |
| F021-H | 2 | -2887.922 | 60.000 | -564.478 | 0.0 | 22.5 | not |
| F021-S | 2 | -2875.337 | 60.000 | -564.075 | 0.0 | 89.7 | not |
| F022-H | 2 | -2886.123 | 60.000 | -563.804 | 0.0 | 73.2 | not |
| F022-S | 2 | -2882.266 | 60.000 | -564.159 | 0.0 | 45.0 | not |
| F023-H | 2 | -2881.015 | 60.000 | -564.416 | 0.0 | 68.7 | not |

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| F023-S | 2 | -2874.410 | 60.000 | -564.341 | 0.0 | 77.7 | not |
| F024-H | 2 | -2880.746 | 60.000 | -564.447 | 0.0 | 32.4 | not |
| F024-S | 2 | -2881.162 | 60.000 | -564.419 | 0.0 | 31.2 | not |
| F025-H | 2 | -2880.994 | 60.000 | -564.494 | 0.0 | 47.7 | not |
| F025-S | 2 | -2874.422 | 60.000 | -563.575 | 0.0 | 63.6 | not |
| F026-H | 2 | -2882.832 | 60.000 | -563.586 | 0.0 | 63.0 | not |
| F026-S | 2 | -2885.159 | 60.000 | -564.299 | 0.0 | 26.7 | not |
| F027-H | 2 | -2881.721 | 60.000 | -563.931 | 0.0 | 58.8 | not |
| F027-S | 2 | -2879.257 | 60.000 | -563.949 | 0.0 | 95.4 | not |
| F028-H | 2 | -2891.834 | 60.000 | -564.111 | 0.0 | 26.4 | not |
| F028-S | 2 | -2883.709 | 60.000 | -564.467 | 0.0 | 23.4 | not |
| F029-H | 2 | -2890.550 | 60.000 | -564.227 | 0.0 | 29.7 | not |
| F029-S | 2 | -3004.680 | 60.000 | -564.383 | 0.0 | 40.8 | CATCH |
| F030-H | 2 | -2886.238 | 60.000 | -564.064 | 0.0 | 53.7 | not |
| F030-S | 2 | -2879.870 | 60.000 | -564.021 | 0.0 | 33.0 | not |
| F031-H | 2 | -2885.825 | 60.000 | -564.488 | 0.0 | 31.8 | not |
| F031-S | 2 | -2878.282 | 60.000 | -564.030 | 0.0 | 70.8 | not |
| F032-H | 2 | -2887.546 | 60.000 | -564.425 | 0.0 | 81.9 | not |
| F032-S | 2 | -2882.526 | 60.000 | -564.384 | 0.0 | 46.5 | not |
| F033-H | 2 | -2880.047 | 60.000 | -564.293 | 0.0 | 58.5 | not |
| F033-S | 2 | -2882.011 | 60.000 | -563.581 | 0.0 | 115.2 | not |
| F034-H | 2 | -2886.385 | 60.000 | -563.270 | 0.0 | 83.1 | not |
| F034-S | 2 | -2880.845 | 60.000 | -564.090 | 0.0 | 45.3 | not |
| F035-H | 2 | -2882.404 | 60.000 | -564.201 | 90.0 | 35.1 | not |
| F035-S | 2 | -2878.984 | 60.000 | -564.340 | 0.0 | 40.5 | not |
| F036-H | 2 | -2883.227 | 60.000 | -564.292 | 0.0 | 29.4 | not |
| F036-S | 2 | -2890.059 | 60.000 | -564.387 | 0.0 | 13.2 | not |
| F037-H | 2 | -3008.613 | 60.000 | -563.633 | 0.0 | 67.2 | CATCH |
| F037-S | 2 | -2879.053 | 60.000 | -563.770 | 0.0 | 79.5 | not |
| F038-H | 2 | -2876.731 | 60.000 | -563.903 | 0.0 | 45.9 | not |
| F038-S | 2 | -2874.414 | 60.000 | -564.017 | 0.0 | 48.0 | not |
| F040-H | 2 | -2891.491 | 60.000 | -564.184 | 0.0 | 34.8 | not |
| F040-S | 2 | -2880.484 | 60.000 | -564.105 | 0.0 | 24.3 | not |
| F041-H | 2 | -3003.748 | 60.000 | -564.011 | 0.0 | 40.5 | CATCH |
| F041-S | 2 | -2991.265 | 60.000 | -563.988 | 0.0 | 42.3 | CATCH |
| F042-H | 2 | -2884.614 | 60.000 | -564.118 | 0.0 | 44.4 | not |
| F042-S | 2 | -2885.588 | 60.000 | -564.103 | 0.0 | 36.0 | not |
| F043-H | 2 | -2880.299 | 60.000 | -564.484 | 0.0 | 15.9 | not |
| F043-S | 2 | -2886.387 | 60.000 | -564.158 | 0.0 | 31.2 | not |
| H001-H | 2 | -2881.996 | 60.000 | -564.233 | 0.0 | 38.7 | not |
| H002-H | 2 | -2890.044 | 60.000 | -564.408 | 0.0 | 18.0 | not |
| H003-H | 2 | -2886.688 | 60.000 | -564.497 | 0.0 | 35.1 | not |
| I001-H | 2 | -2874.426 | 60.000 | -563.942 | 0.0 | 75.9 | not |
| I001-S | 2 | -2878.691 | 60.000 | -563.992 | 0.0 | 36.0 | not |
| P001-H | 2 | -2885.519 | 60.000 | -563.906 | 90.0 | 55.5 | not |
| P001-S | 2 | -2882.365 | 60.000 | -563.852 | 0.0 | 61.8 | not |
| P002-H | 2 | -2886.648 | 60.000 | -563.554 | 0.0 | 68.1 | not |
| P002-S | 2 | -2881.028 | 60.000 | -564.183 | 0.0 | 26.1 | not |
| P003-H | 2 | -2885.083 | 60.000 | -564.349 | 0.0 | 12.9 | not |
| P003-S | 2 | -2874.413 | 60.000 | -564.184 | 0.0 | 21.9 | not |
| P004-H | 2 | -2874.427 | 60.000 | -563.807 | 0.0 | 58.8 | not |
| P004-S | 2 | -2901.585 | 60.000 | -564.378 | 0.0 | 23.1 | not |
| P005-H | 2 | -2886.392 | 60.000 | -564.445 | 0.0 | 23.1 | not |
| P005-S | 2 | -2882.956 | 60.000 | -564.078 | 0.0 | 43.5 | not |
| P006-H | 2 | -2888.980 | 60.000 | -564.124 | 0.0 | 47.4 | not |
| P006-S | 2 | -2883.509 | 60.000 | -564.182 | 0.0 | 21.9 | not |
| P007-H | 2 | -2883.679 | 60.000 | -564.339 | 0.0 | 25.8 | not |
| P007-S | 2 | -2879.194 | 60.000 | -564.439 | 0.0 | 19.2 | not |
| P008-H | 2 | -2874.478 | 60.000 | -563.916 | 0.0 | 63.6 | not |
| P008-S | 2 | -2886.240 | 60.000 | -564.250 | 0.0 | 28.5 | not |

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| P009-H | 2 | -2887.007 | 60.000 | -563.922 | 0.0 | 50.7 | not |
| P009-S | 2 | -2890.017 | 60.000 | -563.926 | 0.0 | 69.9 | not |
| P010-H | 2 | -2874.462 | 60.000 | -563.986 | 0.0 | 45.3 | not |
| P010-S | 2 | -2874.519 | 60.000 | -564.478 | 0.0 | 29.1 | not |

## Task Room 3 Reduced Data

| File | Room | X | Y | Z | Rotate | Speed | RESULT |
|---|---|---|---|---|---|---|---|
| A001-H | 3 | -2481.859 | 60.000 | -617.434 | 0.0 | 45.9 | no |
| A002-H | 3 | -2481.833 | 60.000 | -616.409 | 0.0 | 35.7 | no |
| A003-H | 3 | -2481.590 | 60.000 | -620.698 | 0.0 | 23.7 | no |
| A004-H | 3 | -2481.670 | 125.000 | -713.014 | 0.0 | 30.6 | FLY |
| A005-H | 3 | -2481.482 | 125.000 | -707.317 | 0.0 | 51.0 | FLY |
| B001-H | 3 | -2481.308 | 60.000 | -633.516 | 0.0 | 12.3 | no |
| B001-S | 3 | -2481.400 | 60.000 | -617.711 | 0.0 | 17.4 | no |
| B002-H | 3 | -2481.391 | 60.000 | -626.449 | 0.0 | 27.0 | no |
| B002-S | 3 | -2482.080 | 60.000 | -619.862 | 0.0 | 52.8 | no |
| B003-H | 3 | -2481.685 | 125.000 | -722.857 | 0.0 | 30.0 | FLY |
| B003-S | 3 | -2482.239 | 60.000 | -607.570 | 0.0 | 62.7 | no |
| B004-H | 3 | -2482.141 | 125.000 | -720.901 | 0.0 | 64.8 | FLY |
| B004-S | 3 | -2481.402 | 60.000 | -628.207 | 0.0 | 82.5 | no |
| B005-H | 3 | -2481.684 | 60.000 | -635.357 | 90.0 | 27.9 | m/b |
| B005-S | 3 | -2481.321 | 60.000 | -622.831 | 0.0 | 18.9 | no |
| F001-H | 3 | -2481.475 | 121.000 | -713.204 | 0.0 | 24.3 | FLY |
| F001-S | 3 | -2481.815 | 125.000 | -724.199 | 0.0 | 41.1 | FLY |
| F002-H | 3 | -2481.606 | 125.000 | -712.122 | 0.0 | 69.6 | FLY |
| F002-S | 3 | -2481.780 | 125.000 | -724.420 | 0.0 | 70.5 | FLY |
| F003-H | 3 | -2481.972 | 125.000 | -713.206 | 0.0 | 48.9 | FLY |
| F003-S | 3 | -2482.312 | 125.000 | -715.090 | 0.0 | 110.7 | FLY |
| F004-H | 3 | -2482.092 | 73.000 | -721.118 | 0.0 | 56.7 | FLY |
| F004-S | 3 | -2482.211 | 125.000 | -725.267 | 0.0 | 63.3 | FLY |
| F005-H | 3 | -2481.948 | 125.000 | -714.444 | 0.0 | 140.4 | FLY |
| F005-S | 3 | -2482.187 | 125.000 | -712.131 | 0.0 | 108.6 | FLY |
| F006-H | 3 | -2481.867 | 60.000 | -623.584 | 0.0 | 53.4 | no |
| F006-S | 3 | -2481.668 | 125.000 | -721.459 | 0.0 | 68.4 | FLY |
| F007-H | 3 | -2481.607 | 60.000 | -618.555 | 0.0 | 37.2 | no |
| F007-S | 3 | -2481.938 | 60.000 | -612.351 | 90.0 | 43.2 | m/b |
| F008-H | 3 | -2481.515 | 125.000 | -712.799 | 0.0 | 34.2 | FLY |
| F008-S | 3 | -2481.626 | 125.000 | -710.871 | 0.0 | 37.8 | FLY |
| F009-H | 3 | -2481.381 | 125.000 | -716.496 | 0.0 | 46.2 | FLY |
| F009-S | 3 | -2482.479 | 60.000 | -612.918 | 45.0 | 148.5 | m/b |
| F010-H | 3 | -2481.304 | 125.000 | -717.510 | 0.0 | 62.7 | FLY |
| F010-S | 3 | -2481.458 | 60.000 | -624.766 | 0.0 | 22.2 | no |
| F011-H | 3 | -2481.858 | 60.000 | -630.953 | 0.0 | 41.1 | no |
| F011-S | 3 | -2481.408 | 60.000 | -633.098 | 0.0 | 28.5 | no |
| F012-H | 3 | -2481.353 | 60.000 | -612.608 | 0.0 | 60.6 | no |
| F012-S | 3 | -2481.404 | 60.000 | -619.104 | 0.0 | 38.7 | no |
| F013-H | 3 | -2481.716 | 60.000 | -624.480 | 0.0 | 56.4 | no |
| F013-S | 3 | -2482.635 | 60.000 | -613.317 | 0.0 | 99.3 | no |
| F014-H | 3 | -2481.731 | 60.000 | -616.029 | 0.0 | 54.3 | no |
| F014-S | 3 | -2481.596 | 60.000 | -627.741 | 0.0 | 39.3 | no |
| F015-H | 3 | -2482.016 | 60.000 | -620.988 | 0.0 | 51.6 | no |
| F015-S | 3 | -2481.920 | 60.000 | -620.364 | 0.0 | 59.4 | no |
| F016-H | 3 | -2481.501 | 60.000 | -621.028 | 90.0 | 23.4 | m/b |
| F016-S | 3 | -2481.522 | 125.000 | -710.850 | 0.0 | 18.9 | FLY |
| F017-H | 3 | -2481.614 | 125.000 | -733.301 | 0.0 | 69.0 | FLY |
| F017-S | 3 | -2481.438 | 60.000 | -622.307 | 0.0 | 39.6 | no |
| F018-H | 3 | -2481.307 | 125.000 | -708.485 | 0.0 | 41.4 | FLY |
| F018-S | 3 | -2481.430 | 60.000 | -625.628 | 0.0 | 14.4 | no |
| F019-H | 3 | -2482.561 | 125.000 | -712.932 | 0.0 | 82.5 | FLY |

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|---|---|---|---|---|---|---|---|
| F019-S | 3 | -2481.310 | 119.000 | -713.758 | 0.0 | 72.0 | FLY |
| F020-H | 3 | -2481.411 | 60.000 | -619.783 | 0.0 | 43.5 | no |
| F020-S | 3 | -2481.511 | 60.000 | -620.231 | 0.0 | 31.2 | no |
| F021-H | 3 | -2481.687 | 125.000 | -715.381 | 0.0 | 40.2 | FLY |
| F021-S | 3 | -2482.106 | 60.000 | -618.853 | 0.0 | 76.2 | no |
| F022-H | 3 | -2482.039 | 60.000 | -637.108 | 0.0 | 64.2 | no |
| F022-S | 3 | -2481.471 | 60.000 | -626.989 | 0.0 | 43.5 | no |
| F023-H | 3 | -2481.529 | 125.000 | -728.215 | 0.0 | 27.0 | FLY |
| F023-S | 3 | -2482.171 | 60.000 | -621.315 | 0.0 | 71.7 | no |
| F024-H | 3 | -2481.567 | 125.000 | -727.448 | 0.0 | 46.5 | FLY |
| F024-S | 3 | -2481.424 | 60.000 | -634.669 | 90.0 | 26.4 | m/b |
| F025-H | 3 | -2481.484 | 60.000 | -615.807 | 0.0 | 34.5 | no |
| F025-S | 3 | -2481.337 | 60.000 | -622.217 | 0.0 | 41.1 | no |
| F026-H | 3 | -2481.402 | 60.000 | -618.418 | 0.0 | 37.5 | no |
| F026-S | 3 | -2481.368 | 60.000 | -620.673 | 0.0 | 39.0 | no |
| F027-H | 3 | -2481.629 | 125.000 | -705.402 | 0.0 | 34.2 | FLY |
| F027-S | 3 | -2481.565 | 60.000 | -623.117 | 0.0 | 87.3 | no |
| F028-H | 3 | -2481.749 | 60.000 | -627.018 | 0.0 | 51.6 | no |
| F028-S | 3 | -2481.720 | 60.000 | -636.032 | 0.0 | 42.9 | no |
| F029-H | 3 | -2481.527 | 125.000 | -711.373 | 0.0 | 23.7 | FLY |
| F029-S | 3 | -2481.499 | 60.000 | -616.056 | 0.0 | 32.1 | no |
| F030-H | 3 | -2481.899 | 60.000 | -615.400 | 0.0 | 43.5 | no |
| F030-S | 3 | -2481.271 | 60.000 | -624.677 | 0.0 | 38.4 | no |
| F031-H | 3 | -2481.443 | 60.000 | -622.024 | 0.0 | 24.9 | no |
| F031-S | 3 | -2481.518 | 60.000 | -620.755 | 0.0 | 65.7 | no |
| F032-H | 3 | -2481.713 | 60.000 | -624.150 | 0.0 | 87.0 | no |
| F032-S | 3 | -2481.897 | 60.000 | -623.568 | 0.0 | 51.9 | no |
| F033-H | 3 | -2482.326 | 125.000 | -715.375 | 0.0 | 74.4 | FLY |
| F033-S | 3 | -2481.804 | 98.000 | -721.115 | 0.0 | 114.0 | FLY |
| F034-H | 3 | -2482.567 | 121.000 | -722.362 | 0.0 | 87.3 | FLY |
| F034-S | 3 | -2481.426 | 60.000 | -627.220 | 90.0 | 45.3 | m/b |
| F035-H | 3 | -2481.680 | 63.000 | -714.184 | 0.0 | 28.8 | FLY |
| F035-S | 3 | -2481.345 | 60.000 | -615.889 | 90.0 | 27.9 | m/b |
| F036-H | 3 | -2481.601 | 125.000 | -714.033 | 0.0 | 24.3 | FLY |
| F036-S | 3 | -2481.572 | 125.000 | -709.355 | 0.0 | 20.4 | FLY |
| F037-H | 3 | -2481.678 | 60.000 | -635.245 | 0.0 | 45.0 | no |
| F037-S | 3 | -2481.303 | 60.000 | -622.205 | 0.0 | 54.3 | no |
| F038-H | 3 | -2481.519 | 68.000 | -710.922 | 0.0 | 67.8 | FLY |
| F038-S | 3 | -2482.386 | 76.000 | -713.833 | 0.0 | 72.9 | FLY |
| F040-H | 3 | -2481.628 | 60.000 | -625.014 | 0.0 | 35.1 | no |
| F040-S | 3 | -2481.557 | 60.000 | -614.106 | 0.0 | 25.8 | no |
| F041-H | 3 | -2481.613 | 60.000 | -634.319 | 0.0 | 29.4 | no |
| F041-S | 3 | -2481.638 | 60.000 | -632.947 | 0.0 | 31.2 | no |
| F042-H | 3 | -2481.484 | 60.000 | -626.642 | 0.0 | 38.7 | no |
| F042-S | 3 | -2481.546 | 60.000 | -629.784 | 0.0 | 21.9 | no |
| F043-H | 3 | -2481.591 | 60.000 | -620.237 | 0.0 | 23.1 | no |
| F043-S | 3 | -2481.745 | 60.000 | -622.046 | 0.0 | 34.5 | no |
| H001-H | 3 | -2481.422 | 60.000 | -612.151 | 0.0 | 39.0 | no |
| H002-H | 3 | -2481.371 | 60.000 | -624.325 | 0.0 | 17.1 | no |
| H003-H | 3 | -2481.369 | 125.000 | -731.211 | 0.0 | 31.5 | FLY |
| I001-H | 3 | -2481.383 | 117.000 | -718.549 | 0.0 | 39.0 | FLY |
| I001-S | 3 | -2481.553 | 60.000 | -618.970 | 0.0 | 24.6 | no |
| P001-H | 3 | -2481.873 | 154.000 | -708.284 | 0.0 | 48.3 | FLY |
| P001-S | 3 | -2481.793 | 248.000 | -701.468 | 0.0 | 57.6 | FLY |
| P002-H | 3 | -2481.802 | 60.000 | -633.407 | 0.0 | 78.6 | no |
| P002-S | 3 | -2481.777 | 120.000 | -711.087 | 0.0 | 44.4 | FLY |
| P003-H | 3 | -2481.300 | 60.000 | -633.214 | 0.0 | 12.9 | no |
| P003-S | 3 | -2481.485 | 60.000 | -622.239 | 0.0 | 24.0 | no |
| P004-H | 3 | -2481.361 | 60.000 | -634.101 | 90.0 | 50.4 | m/b |
| P004-S | 3 | -2481.648 | 60.000 | -620.843 | 0.0 | 29.4 | no |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| P005-H | 3 | -2481.381 | 152.000 | -702.515 | 0.0 | 18.3 | FLY |
| P005-S | 3 | -2481.312 | 158.000 | -711.241 | 0.0 | 45.3 | FLY |
| P006-H | 3 | -2481.752 | 60.000 | -625.742 | 0.0 | 54.3 | no |
| P006-S | 3 | -2481.466 | 60.000 | -623.996 | 0.0 | 21.0 | no |
| P007-H | 3 | -2481.424 | 250.000 | -663.581 | 0.0 | 46.2 | FLY |
| P007-S | 3 | -2481.547 | 250.000 | -671.354 | 0.0 | 28.5 | FLY |
| P008-H | 3 | -2482.333 | 60.000 | -721.223 | 0.0 | 67.8 | no |
| P008-S | 3 | -2481.349 | 196.000 | -717.523 | 0.0 | 40.2 | FLY |
| P009-H | 3 | -2481.606 | 156.000 | -706.062 | 0.0 | 34.2 | FLY |
| P009-S | 3 | -2482.093 | 140.000 | -704.627 | 0.0 | 96.6 | FLY |
| P010-H | 3 | -2481.935 | 60.000 | -631.309 | 0.0 | 47.1 | no |
| P010-S | 3 | -2481.728 | 60.000 | -645.090 | 0.0 | 43.8 | no |

## Task Room 4 Reduced Data

| File | Room | X | Y | Z | Rotate | Speed | RESULT |
|---|---|---|---|---|---|---|---|
| A001-H | 4 | -2344.832 | 60.000 | -221.714 | 90.0 | 49.5 | ROTATE |
| A002-H | 4 | -2346.762 | 60.000 | -221.742 | 90.0 | 35.1 | ROTATE |
| A003-H | 4 | -2343.354 | 60.000 | -221.774 | 90.0 | 30.9 | ROTATE |
| A004-H | 4 | -2343.870 | 60.000 | -222.091 | 0.0 | 69.6 | no |
| A005-H | 4 | -2341.650 | 60.000 | -222.530 | 90.0 | 85.8 | ROTATE |
| B001-H | 4 | -2334.710 | 60.000 | -221.507 | 0.0 | 13.5 | no |
| B001-S | 4 | -2359.634 | 60.000 | -221.805 | 0.0 | 22.2 | no |
| B002-H | 4 | -2335.057 | 60.000 | -221.593 | 90.0 | 37.2 | ROTATE |
| B002-S | 4 | -2358.431 | 60.000 | -222.569 | 0.0 | 69.9 | no |
| B003-H | 4 | -2332.665 | 60.000 | -221.570 | 0.0 | 38.1 | no |
| B003-S | 4 | -2360.673 | 60.000 | -222.209 | 0.0 | 58.2 | no |
| B004-H | 4 | -2334.902 | 60.000 | -222.269 | 69.0 | 55.2 | ROTATE |
| B004-S | 4 | -2358.103 | 60.000 | -222.284 | 0.0 | 74.4 | no |
| B005-H | 4 | -2336.080 | 60.000 | -221.826 | 90.0 | 21.3 | ROTATE |
| B005-S | 4 | -2354.984 | 60.000 | -221.824 | 0.0 | 41.1 | no |
| F001-H | 4 | -2358.067 | 60.000 | -221.696 | 0.0 | 22.5 | no |
| F001-S | 4 | -2359.879 | 60.000 | -221.540 | 90.0 | 66.0 | ROTATE |
| F002-H | 4 | -2356.503 | 60.000 | -222.872 | 90.0 | 98.1 | ROTATE |
| F002-S | 4 | -2358.592 | 60.000 | -222.328 | 90.0 | 77.7 | ROTATE |
| F003-H | 4 | -2349.964 | 60.000 | -222.050 | 90.0 | 90.9 | ROTATE |
| F003-S | 4 | -2359.009 | 60.000 | -222.300 | 66.0 | 127.8 | ROTATE |
| F004-H | 4 | -2360.862 | 60.000 | -222.955 | 0.0 | 94.8 | no |
| F004-S | 4 | -2352.895 | 60.000 | -222.198 | 0.0 | 66.9 | no |
| F005-H | 4 | -2356.644 | 60.000 | -221.956 | 90.0 | 47.1 | ROTATE |
| F005-S | 4 | -2357.422 | 60.000 | -221.737 | 0.0 | 95.7 | no |
| F006-H | 4 | -2358.169 | 60.000 | -222.535 | 0.0 | 88.8 | no |
| F006-S | 4 | -2356.614 | 60.000 | -221.946 | 0.0 | 63.3 | no |
| F007-H | 4 | -2358.475 | 60.000 | -221.526 | 0.0 | 65.1 | no |
| F007-S | 4 | -2358.507 | 60.000 | -221.614 | 0.0 | 54.6 | no |
| F008-H | 4 | -2358.201 | 60.000 | -221.602 | 69.0 | 37.5 | ROTATE |
| F008-S | 4 | -2357.485 | 60.000 | -221.667 | 0.0 | 25.8 | no |
| F009-H | 4 | -2353.980 | 60.000 | -222.582 | 90.0 | 85.5 | ROTATE |
| F009-S | 4 | -2358.360 | 60.000 | -222.499 | 0.0 | 147.6 | no |
| F010-H | 4 | -2354.355 | 60.000 | -222.297 | 90.0 | 63.6 | ROTATE |
| F010-S | 4 | -2358.484 | 60.000 | -221.536 | 0.0 | 12.6 | no |
| F011-H | 4 | -2361.468 | 60.000 | -221.667 | 0.0 | 27.3 | no |
| F011-S | 4 | -2358.713 | 60.000 | -221.760 | 0.0 | 25.5 | no |
| F012-H | 4 | -2363.801 | 60.000 | -221.738 | 0.0 | 50.7 | no |
| F012-S | 4 | -2364.439 | 60.000 | -221.855 | 0.0 | 28.8 | no |
| F013-H | 4 | -2357.674 | 60.000 | -222.253 | 0.0 | 48.6 | no |
| F013-S | 4 | -2355.001 | 60.000 | -221.564 | 0.0 | 112.8 | no |
| F014-H | 4 | -2360.108 | 60.000 | -222.149 | 0.0 | 49.8 | no |
| F014-S | 4 | -2354.160 | 60.000 | -221.675 | 0.0 | 47.4 | no |
| F015-H | 4 | -2360.857 | 60.000 | -221.962 | 0.0 | 78.0 | no |

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|---|---|---|---|---|---|---|---|
| F015-S | 4 | -2359.743 | 60.000 | -222.099 | 0.0 | 50.1 | no |
| F016-H | 4 | -2358.495 | 60.000 | -221.726 | 90.0 | 18.0 | ROTATE |
| F016-S | 4 | -2359.820 | 60.000 | -221.949 | 90.0 | 57.9 | ROTATE |
| F017-H | 4 | -2357.738 | 60.000 | -221.545 | 0.0 | 33.6 | no |
| F017-S | 4 | -2356.956 | 60.000 | -221.685 | 0.0 | 48.0 | no |
| F018-H | 4 | -2358.556 | 60.000 | -222.227 | 0.0 | 53.4 | no |
| F018-S | 4 | -2360.597 | 60.000 | -221.506 | 0.0 | 26.7 | no |
| F019-H | 4 | -2362.172 | 60.000 | -222.403 | 90.0 | 62.7 | ROTATE |
| F019-S | 4 | -2357.720 | 60.000 | -222.540 | 72.0 | 99.9 | ROTATE |
| F020-H | 4 | -2357.337 | 60.000 | -221.759 | 0.0 | 46.8 | no |
| F020-S | 4 | -2358.426 | 60.000 | -221.975 | 0.0 | 30.9 | no |
| F021-H | 4 | -2361.115 | 60.000 | -222.015 | 0.0 | 65.4 | no |
| F021-S | 4 | -2359.496 | 60.000 | -222.368 | 0.0 | 94.5 | no |
| F022-H | 4 | -2342.152 | 60.000 | -222.788 | 0.0 | 99.0 | no |
| F022-S | 4 | -2354.867 | 60.000 | -222.211 | 0.0 | 46.8 | no |
| F023-H | 4 | -2358.163 | 60.000 | -221.969 | 0.0 | 40.5 | no |
| F023-S | 4 | -2362.347 | 60.000 | -222.270 | 0.0 | 72.9 | no |
| F024-H | 4 | -2355.128 | 60.000 | -222.019 | 90.0 | 47.4 | ROTATE |
| F024-S | 4 | -2357.394 | 60.000 | -221.608 | 0.0 | 24.3 | no |
| F025-H | 4 | -2361.234 | 60.000 | -221.765 | 0.0 | 27.6 | no |
| F025-S | 4 | -2358.761 | 60.000 | -222.056 | 0.0 | 47.4 | no |
| F026-H | 4 | -2355.074 | 60.000 | -222.585 | 0.0 | 85.2 | no |
| F026-S | 4 | -2357.184 | 60.000 | -221.655 | 0.0 | 54.6 | no |
| F027-H | 4 | -2357.118 | 60.000 | -221.850 | 0.0 | 46.8 | no |
| F027-S | 4 | -2356.123 | 60.000 | -222.986 | 0.0 | 103.2 | no |
| F028-H | 4 | -2356.532 | 60.000 | -222.721 | 0.0 | 90.0 | no |
| F028-S | 4 | -2361.020 | 60.000 | -221.571 | 0.0 | 150.0 | no |
| F029-H | 4 | -2357.980 | 60.000 | -221.503 | 90.0 | 45.3 | ROTATE |
| F029-S | 4 | -2357.523 | 60.000 | -221.777 | 90.0 | 47.1 | ROTATE |
| F030-H | 4 | -2359.433 | 60.000 | -222.040 | 0.0 | 43.2 | no |
| F030-S | 4 | -2360.308 | 60.000 | -221.945 | 0.0 | 53.1 | no |
| F031-H | 4 | -2360.347 | 60.000 | -221.845 | 0.0 | 35.7 | no |
| F031-S | 4 | -2361.634 | 60.000 | -221.582 | 0.0 | 62.4 | no |
| F032-H | 4 | -2363.446 | 60.000 | -221.668 | 0.0 | 103.5 | no |
| F032-S | 4 | -2354.766 | 60.000 | -222.020 | 0.0 | 45.3 | no |
| F033-H | 4 | -2355.875 | 60.000 | -222.090 | 0.0 | 75.9 | no |
| F033-S | 4 | -2359.464 | 60.000 | -222.352 | 0.0 | 139.5 | no |
| F034-H | 4 | -2358.201 | 60.000 | -222.094 | 0.0 | 71.1 | no |
| F034-S | 4 | -2358.733 | 60.000 | -221.911 | 0.0 | 54.6 | no |
| F035-H | 4 | -2358.368 | 60.000 | -221.876 | 90.0 | 35.7 | ROTATE |
| F035-S | 4 | -2360.066 | 60.000 | -221.635 | 90.0 | 42.3 | ROTATE |
| F036-H | 4 | -2360.279 | 60.000 | -222.060 | 0.0 | 46.5 | no |
| F036-S | 4 | -2356.090 | 60.000 | -221.704 | 90.0 | 32.1 | ROTATE |
| F037-H | 4 | -2357.879 | 60.000 | -221.546 | 0.0 | 39.9 | no |
| F037-S | 4 | -2359.775 | 60.000 | -221.898 | 0.0 | 69.3 | no |
| F038-H | 4 | -2348.386 | 60.000 | -221.519 | 0.0 | 70.2 | no |
| F038-S | 4 | -2356.900 | 60.000 | -222.348 | 0.0 | 69.0 | no |
| F040-H | 4 | -2360.638 | 60.000 | -221.502 | 0.0 | 41.4 | no |
| F040-S | 4 | -2358.966 | 60.000 | -222.111 | 0.0 | 42.0 | no |
| F041-H | 4 | -2356.357 | 60.000 | -221.758 | 0.0 | 20.4 | no |
| F041-S | 4 | -2358.274 | 60.000 | -221.982 | 18.0 | 34.2 | ROTATE |
| F042-H | 4 | -2358.652 | 60.000 | -221.598 | 0.0 | 40.8 | no |
| F042-S | 4 | -2359.727 | 60.000 | -221.850 | 0.0 | 23.1 | no |
| F043-H | 4 | -2362.227 | 60.000 | -221.501 | 0.0 | 18.6 | no |
| F043-S | 4 | -2356.812 | 60.000 | -221.644 | 0.0 | 30.9 | no |
| H001-H | 4 | -2359.275 | 60.000 | -221.964 | 0.0 | 45.6 | no |
| H002-H | 4 | -2357.697 | 60.000 | -221.848 | 0.0 | 26.4 | no |
| H003-H | 4 | -2358.149 | 60.000 | -221.634 | 0.0 | 39.9 | no |
| I001-H | 4 | -2362.430 | 60.000 | -221.508 | 0.0 | 81.6 | no |
| I001-S | 4 | -2361.924 | 60.000 | -221.940 | 0.0 | 33.9 | no |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| P001-H | 4 | -2355.639 | 60.000 | -222.222 | 63.0 | 78.9 | ROTATE |
| P001-S | 4 | -2358.224 | 60.000 | -222.454 | 0.0 | 71.7 | no |
| P002-H | 4 | -2355.066 | 60.000 | -222.013 | 90.0 | 79.5 | ROTATE |
| P002-S | 4 | -2359.857 | 60.000 | -221.870 | 0.0 | 54.6 | no |
| P003-H | 4 | -2359.249 | 60.000 | -221.586 | 90.0 | 10.8 | ROTATE |
| P003-S | 4 | -2357.335 | 60.000 | -221.536 | 0.0 | 24.9 | no |
| P004-H | 4 | -2353.687 | 60.000 | -221.573 | 90.0 | 42.0 | ROTATE |
| P004-S | 4 | -2357.402 | 60.000 | -221.714 | 0.0 | 36.6 | no |
| P005-H | 4 | -2357.466 | 60.000 | -221.661 | 0.0 | 38.7 | no |
| P005-S | 4 | -2357.102 | 60.000 | -221.947 | 90.0 | 81.6 | ROTATE |
| P006-H | 4 | -2355.223 | 60.000 | -221.758 | 0.0 | 27.0 | no |
| P006-S | 4 | -2358.195 | 60.000 | -221.958 | 0.0 | 45.9 | no |
| P007-H | 4 | -2360.704 | 60.000 | -221.914 | 0.0 | 49.8 | no |
| P007-S | 4 | -2358.149 | 60.000 | -221.789 | 0.0 | 20.7 | no |
| P008-H | 4 | -2347.134 | 60.000 | -221.830 | 0.0 | 53.1 | no |
| P008-S | 4 | -2355.877 | 60.000 | -222.006 | 0.0 | 52.2 | no |
| P009-H | 4 | -2361.513 | 60.000 | -222.553 | 0.0 | 69.6 | no |
| P009-S | 4 | -2359.495 | 60.000 | -222.940 | 0.0 | 143.4 | no |
| P010-H | 4 | -2350.182 | 60.000 | -222.385 | 0.0 | 65.4 | no |
| P010-S | 4 | -2356.389 | 60.000 | -222.066 | 0.0 | 36.3 | no |

## Task Room 5 Reduced Data

| File | Room | X | Y | Z | Rotate | Speed | RESULT |
|---|---|---|---|---|---|---|---|
| A001-H | 5 | -1892.275 | 60.000 | -153.655 | 0.0 | 56.4 | CATCH |
| A002-H | 5 | -1892.052 | 60.000 | -30.141 | 0.0 | 48.0 | not |
| A003-H | 5 | -1892.447 | 60.000 | -142.843 | 0.0 | 43.8 | CATCH |
| A004-H | 5 | -1891.944 | 60.000 | -149.713 | 0.0 | 76.5 | CATCH |
| A005-H | 5 | -1891.789 | 60.000 | -139.851 | 0.0 | 45.9 | CATCH |
| B001-H | 5 | -1891.907 | 60.000 | -150.231 | 0.0 | 15.9 | CATCH |
| B001-S | 5 | -1891.761 | 60.000 | -143.561 | 0.0 | 22.2 | CATCH |
| B002-H | 5 | -1892.477 | 60.000 | -147.343 | 0.0 | 45.3 | CATCH |
| B002-S | 5 | -1892.166 | 60.000 | -148.458 | 0.0 | 59.1 | CATCH |
| B003-H | 5 | -1891.857 | 60.000 | -151.756 | 0.0 | 41.7 | CATCH |
| B003-S | 5 | -1892.417 | 60.000 | -146.790 | 0.0 | 64.5 | CATCH |
| B004-H | 5 | -1892.323 | 60.000 | -149.031 | 0.0 | 63.6 | CATCH |
| B004-S | 5 | -1892.969 | 60.000 | -148.331 | 0.0 | 87.9 | CATCH |
| B005-H | 5 | -1891.838 | 60.000 | -52.291 | 0.0 | 54.3 | not |
| B005-S | 5 | -1891.914 | 60.000 | -140.863 | 0.0 | 20.7 | CATCH |
| F001-H | 5 | -1891.850 | 60.000 | -153.151 | 0.0 | 30.9 | CATCH |
| F001-S | 5 | -1891.964 | 60.000 | -152.276 | 0.0 | 37.2 | CATCH |
| F002-H | 5 | -1892.219 | 60.000 | -48.053 | 0.0 | 78.6 | not |
| F002-S | 5 | -1892.475 | 60.000 | -55.443 | 0.0 | 63.3 | not |
| F003-H | 5 | -1891.825 | 60.000 | -148.040 | 0.0 | 37.2 | CATCH |
| F003-S | 5 | -1891.779 | 60.000 | -131.844 | 0.0 | 145.8 | CATCH |
| F004-H | 5 | -1892.751 | 60.000 | -125.678 | 0.0 | 109.8 | CATCH |
| F004-S | 5 | -1892.410 | 60.000 | -141.256 | 0.0 | 45.3 | CATCH |
| F005-H | 5 | -1892.376 | 60.000 | -96.059 | 0.0 | 150.0 | not |
| F005-S | 5 | -1892.875 | 60.000 | -143.228 | 0.0 | 93.9 | CATCH |
| F006-H | 5 | -1893.196 | 60.000 | -153.472 | 0.0 | 88.8 | CATCH |
| F006-S | 5 | -1892.504 | 60.000 | -151.210 | 0.0 | 61.2 | CATCH |
| F007-H | 5 | -1892.537 | 60.000 | -143.710 | 0.0 | 52.2 | CATCH |
| F007-S | 5 | -1891.896 | 60.000 | -138.623 | 0.0 | 57.9 | CATCH |
| F008-H | 5 | -1892.221 | 60.000 | -145.087 | 0.0 | 38.7 | CATCH |
| F008-S | 5 | -1892.437 | 60.000 | -142.533 | 0.0 | 41.1 | CATCH |
| F009-H | 5 | -1892.179 | 60.000 | -150.071 | 90.0 | 63.9 | CATCH |
| F009-S | 5 | -1892.814 | 98.000 | -138.825 | 0.0 | 147.3 | CATCH |
| F010-H | 5 | -1892.296 | 60.000 | -148.023 | 0.0 | 83.7 | CATCH |
| F010-S | 5 | -1892.031 | 60.000 | -147.923 | 0.0 | 39.9 | CATCH |
| F011-H | 5 | -1891.804 | 60.000 | -152.526 | 0.0 | 24.6 | CATCH |

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|---|---|---|---|---|---|---|---|
| F011-S | 5 | -1892.442 | 60.000 | -29.383 | 0.0 | 48.6 | not |
| F012-H | 5 | -1892.321 | 60.000 | -142.578 | 0.0 | 44.4 | CATCH |
| F012-S | 5 | -1892.270 | 60.000 | -142.221 | 0.0 | 42.6 | CATCH |
| F013-H | 5 | -1892.747 | 60.000 | -148.755 | 0.0 | 67.8 | CATCH |
| F013-S | 5 | -1892.067 | 60.000 | -133.125 | 0.0 | 121.5 | CATCH |
| F014-H | 5 | -1892.567 | 60.000 | -146.829 | 0.0 | 55.2 | CATCH |
| F014-S | 5 | -1892.394 | 60.000 | -152.298 | 0.0 | 58.8 | CATCH |
| F015-H | 5 | -1892.823 | 60.000 | -144.968 | 0.0 | 73.8 | CATCH |
| F015-S | 5 | -1892.340 | 60.000 | -142.005 | 0.0 | 74.4 | CATCH |
| F016-H | 5 | -1891.890 | 60.000 | -145.204 | 90.0 | 15.3 | CATCH |
| F016-S | 5 | -1892.019 | 66.000 | -42.464 | 18.0 | 54.3 | not |
| F017-H | 5 | -1892.428 | 60.000 | -151.684 | 0.0 | 41.4 | CATCH |
| F017-S | 5 | -1891.815 | 60.000 | -140.163 | 0.0 | 45.6 | CATCH |
| F018-H | 5 | -1892.197 | 60.000 | -151.687 | 0.0 | 46.2 | CATCH |
| F018-S | 5 | -1891.907 | 60.000 | -146.580 | 0.0 | 31.5 | CATCH |
| F019-H | 5 | -1892.406 | 60.000 | -141.110 | 0.0 | 49.5 | CATCH |
| F019-S | 5 | -1891.866 | 60.000 | -143.040 | 0.0 | 56.7 | CATCH |
| F020-H | 5 | -1892.561 | 60.000 | -148.327 | 0.0 | 50.1 | CATCH |
| F020-S | 5 | -1892.265 | 60.000 | -145.001 | 0.0 | 41.4 | CATCH |
| F021-H | 5 | -1892.146 | 60.000 | -144.883 | 0.0 | 72.3 | CATCH |
| F021-S | 5 | -1892.063 | 60.000 | -140.792 | 0.0 | 91.5 | CATCH |
| F022-H | 5 | -1892.073 | 60.000 | -149.503 | 0.0 | 71.1 | CATCH |
| F022-S | 5 | -1892.331 | 60.000 | -143.273 | 0.0 | 50.7 | CATCH |
| F023-H | 5 | -1892.166 | 60.000 | -148.825 | 0.0 | 50.4 | CATCH |
| F023-S | 5 | -1891.938 | 60.000 | -149.367 | 0.0 | 80.7 | CATCH |
| F024-H | 5 | -1891.832 | 60.000 | -148.592 | 90.0 | 34.5 | CATCH |
| F024-S | 5 | -1892.046 | 60.000 | -151.478 | 0.0 | 26.7 | CATCH |
| F025-H | 5 | -1892.233 | 60.000 | -148.553 | 0.0 | 49.5 | CATCH |
| F025-S | 5 | -1892.334 | 60.000 | -146.512 | 0.0 | 67.5 | CATCH |
| F026-H | 5 | -1892.287 | 60.000 | -143.756 | 0.0 | 67.5 | CATCH |
| F026-S | 5 | -1891.776 | 60.000 | -147.045 | 0.0 | 36.6 | CATCH |
| F027-H | 5 | -1892.476 | 60.000 | -147.438 | 0.0 | 52.5 | CATCH |
| F027-S | 5 | -1891.989 | 60.000 | -148.668 | 0.0 | 78.3 | CATCH |
| F028-H | 5 | -1892.404 | 60.000 | -148.308 | 0.0 | 99.9 | CATCH |
| F028-S | 5 | -1891.815 | 60.000 | -142.126 | 0.0 | 21.6 | CATCH |
| F029-H | 5 | -1892.121 | 60.000 | -146.563 | 90.0 | 43.8 | CATCH |
| F029-S | 5 | -1891.878 | 60.000 | -25.022 | 0.0 | 25.8 | not |
| F030-H | 5 | -1891.758 | 60.000 | -35.841 | 0.0 | 51.0 | not |
| F030-S | 5 | -1891.912 | 60.000 | -145.185 | 0.0 | 56.7 | CATCH |
| F031-H | 5 | -1892.185 | 60.000 | -146.999 | 0.0 | 38.7 | CATCH |
| F031-S | 5 | -1892.232 | 60.000 | -142.096 | 0.0 | 69.3 | CATCH |
| F032-H | 5 | -1892.698 | 60.000 | -148.045 | 0.0 | 66.3 | CATCH |
| F032-S | 5 | -1892.001 | 60.000 | -147.554 | 0.0 | 65.4 | CATCH |
| F033-H | 5 | -1891.993 | 60.000 | -34.237 | 0.0 | 48.9 | not |
| F033-S | 5 | -1893.881 | 60.000 | -144.915 | 0.0 | 132.3 | CATCH |
| F034-H | 5 | -1892.780 | 60.000 | -154.598 | 0.0 | 69.3 | CATCH |
| F034-S | 5 | -1891.907 | 60.000 | -151.472 | 0.0 | 64.8 | CATCH |
| F035-H | 5 | -1892.192 | 60.000 | -143.107 | 90.0 | 33.0 | CATCH |
| F035-S | 5 | -1891.860 | 60.000 | -143.963 | 90.0 | 34.2 | CATCH |
| F036-H | 5 | -1891.993 | 60.000 | -145.599 | 0.0 | 43.8 | CATCH |
| F036-S | 5 | -1891.874 | 60.000 | -33.384 | 0.0 | 20.7 | not |
| F037-H | 5 | -1892.335 | 60.000 | -146.273 | 0.0 | 43.8 | CATCH |
| F037-S | 5 | -1892.302 | 60.000 | -145.809 | 0.0 | 79.5 | CATCH |
| F038-H | 5 | -1892.000 | 60.000 | -155.716 | 0.0 | 48.6 | CATCH |
| F038-S | 5 | -1892.361 | 60.000 | -154.952 | 0.0 | 48.3 | CATCH |
| F040-H | 5 | -1891.875 | 60.000 | -148.215 | 0.0 | 36.3 | CATCH |
| F040-S | 5 | -1892.125 | 60.000 | -144.605 | 0.0 | 31.8 | CATCH |
| F041-H | 5 | -1891.782 | 60.000 | -151.350 | 0.0 | 12.6 | CATCH |
| F041-S | 5 | -1891.751 | 60.000 | -152.126 | 0.0 | 37.5 | CATCH |
| F042-H | 5 | -1892.140 | 60.000 | -152.471 | 0.0 | 46.5 | CATCH |

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|---|---|---|---|---|---|---|---|
| F042-S | 5 | -1892.314 | 60.000 | -149.739 | 0.0 | 45.6 | CATCH |
| F043-H | 5 | -1892.046 | 60.000 | -146.035 | 0.0 | 27.3 | CATCH |
| F043-S | 5 | -1891.999 | 60.000 | -37.579 | 0.0 | 26.4 | not |
| H001-H | 5 | -1892.111 | 60.000 | -149.560 | 0.0 | 37.5 | CATCH |
| H002-H | 5 | -1892.086 | 60.000 | -150.133 | 0.0 | 40.2 | CATCH |
| H003-H | 5 | -1891.879 | 60.000 | -149.726 | 0.0 | 48.9 | CATCH |
| I001-H | 5 | -1892.702 | 60.000 | -151.004 | 0.0 | 59.4 | CATCH |
| I001-S | 5 | -1892.345 | 60.000 | -41.255 | 0.0 | 45.6 | not |
| P001-H | 5 | -1892.375 | 60.000 | -33.208 | 81.0 | 65.1 | not |
| P001-S | 5 | -1892.181 | 60.000 | -137.093 | 0.0 | 63.6 | CATCH |
| P002-H | 5 | -1892.606 | 60.000 | -51.416 | 0.0 | 58.5 | not |
| P002-S | 5 | -1892.058 | 60.000 | -43.072 | 0.0 | 51.9 | not |
| P003-H | 5 | -1891.950 | 60.000 | -153.933 | 0.0 | 13.8 | CATCH |
| P003-S | 5 | -1892.006 | 60.000 | -145.916 | 0.0 | 38.4 | CATCH |
| P004-H | 5 | -1891.837 | 60.000 | -148.834 | 0.0 | 56.1 | CATCH |
| P004-S | 5 | -1892.089 | 60.000 | -151.695 | 0.0 | 42.3 | CATCH |
| P005-H | 5 | -1892.214 | 60.000 | -144.263 | 0.0 | 30.0 | CATCH |
| P005-S | 5 | -1891.996 | 60.000 | -147.352 | 90.0 | 41.4 | CATCH |
| P006-H | 5 | -1892.544 | 60.000 | -153.013 | 0.0 | 58.5 | CATCH |
| P006-S | 5 | -1892.137 | 60.000 | -146.953 | 0.0 | 41.7 | CATCH |
| P007-H | 5 | -1891.849 | 60.000 | -154.641 | 0.0 | 11.7 | CATCH |
| P007-S | 5 | -1891.824 | 60.000 | -150.178 | 0.0 | 37.5 | CATCH |
| P008-H | 5 | -1892.171 | 60.000 | -147.812 | 0.0 | 69.0 | CATCH |
| P008-S | 5 | -1892.252 | 60.000 | -145.525 | 0.0 | 122.4 | CATCH |
| P009-H | 5 | -1892.456 | 60.000 | -143.397 | 0.0 | 57.0 | CATCH |
| P009-S | 5 | -1892.932 | 60.000 | -146.711 | 0.0 | 121.8 | CATCH |
| P010-H | 5 | -1892.343 | 60.000 | -137.826 | 0.0 | 59.1 | CATCH |
| P010-S | 5 | -1891.795 | 60.000 | -155.469 | 0.0 | 19.8 | CATCH |

## Task Room 6 Reduced Data

| File | Room | X | Y | Z | Rotate | Speed | RESULT |
|---|---|---|---|---|---|---|---|
| A001-H | 6 | -1825.640 | 60.000 | -564.137 | 63.0 | 38.4 | m/b |
| A002-H | 6 | -1818.802 | 60.000 | -563.887 | 0.0 | 61.2 | no |
| A003-H | 6 | -1824.991 | 60.000 | -563.901 | 90.0 | 42.6 | m/b |
| A004-H | 6 | -1814.629 | 60.000 | -563.546 | 0.0 | 84.3 | no |
| A005-H | 6 | -1816.422 | 60.000 | -564.358 | 0.0 | 62.7 | no |
| B001-H | 6 | -1816.432 | 60.000 | -564.473 | 0.0 | 15.0 | no |
| B001-S | 6 | -1726.895 | 95.000 | -564.321 | 0.0 | 16.5 | FLY |
| B002-H | 6 | -1717.786 | 125.000 | -564.424 | 0.0 | 47.1 | FLY |
| B002-S | 6 | -1705.721 | 125.000 | -563.966 | 0.0 | 57.0 | FLY |
| B003-H | 6 | -1821.533 | 60.000 | -564.246 | 0.0 | 50.7 | no |
| B003-S | 6 | -1726.027 | 71.000 | -563.636 | 0.0 | 67.8 | FLY |
| B004-H | 6 | -1722.231 | 125.000 | -563.812 | 0.0 | 72.9 | FLY |
| B004-S | 6 | -1713.977 | 125.000 | -563.264 | 0.0 | 84.9 | FLY |
| B005-H | 6 | -1726.054 | 60.000 | -564.328 | 0.0 | 21.9 | no |
| B005-S | 6 | -1809.324 | 60.000 | -564.357 | 0.0 | 32.1 | no |
| F001-H | 6 | -1709.612 | 60.000 | -564.235 | 0.0 | 16.8 | no |
| F001-S | 6 | -1693.123 | 125.000 | -564.384 | 0.0 | 31.2 | FLY |
| F002-H | 6 | -1730.390 | 109.000 | -563.086 | 0.0 | 99.0 | FLY |
| F002-S | 6 | -1731.249 | 107.000 | -563.999 | 0.0 | 65.1 | FLY |
| F003-H | 6 | -1733.375 | 125.000 | -564.384 | 0.0 | 63.9 | FLY |
| F003-S | 6 | -1727.452 | 125.000 | -564.263 | 0.0 | 150.0 | FLY |
| F004-H | 6 | -1816.752 | 60.000 | -563.334 | 0.0 | 109.8 | no |
| F004-S | 6 | -1707.060 | 121.000 | -563.991 | 0.0 | 65.7 | FLY |
| F005-H | 6 | -1722.442 | 125.000 | -562.227 | 0.0 | 136.2 | FLY |
| F005-S | 6 | -1717.314 | 123.000 | -562.685 | 0.0 | 150.0 | FLY |
| F006-H | 6 | -1717.447 | 115.000 | -563.760 | 0.0 | 89.4 | FLY |
| F006-S | 6 | -1716.806 | 107.000 | -563.978 | 0.0 | 72.3 | FLY |
| F007-H | 6 | -1720.936 | 125.000 | -564.205 | 0.0 | 53.7 | FLY |

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|---|---|---|---|---|---|---|---|
| F007-S | 6 | -1718.954 | 125.000 | -564.195 | 0.0 | 40.2 | FLY |
| F008-H | 6 | -1731.036 | 125.000 | -564.078 | 0.0 | 41.7 | FLY |
| F008-S | 6 | -1732.179 | 125.000 | -563.999 | 0.0 | 57.9 | FLY |
| F009-H | 6 | -1724.661 | 125.000 | -563.585 | 0.0 | 61.5 | FLY |
| F009-S | 6 | -1715.659 | 125.000 | -563.346 | 0.0 | 129.0 | FLY |
| F010-H | 6 | -1731.313 | 125.000 | -563.927 | 0.0 | 87.3 | FLY |
| F010-S | 6 | -1713.143 | 125.000 | -564.243 | 0.0 | 29.1 | FLY |
| F011-H | 6 | -1815.555 | 60.000 | -564.213 | 0.0 | 37.2 | no |
| F011-S | 6 | -1729.834 | 121.000 | -564.317 | 0.0 | 26.7 | FLY |
| F012-H | 6 | -1735.536 | 65.000 | -564.236 | 0.0 | 74.7 | FLY |
| F012-S | 6 | -1723.995 | 81.000 | -564.355 | 0.0 | 67.2 | FLY |
| F013-H | 6 | -1711.106 | 69.000 | -564.175 | 0.0 | 65.4 | FLY |
| F013-S | 6 | -1806.203 | 60.000 | -563.574 | 0.0 | 119.4 | no |
| F014-H | 6 | -1735.051 | 87.000 | -564.213 | 0.0 | 47.4 | FLY |
| F014-S | 6 | -1722.778 | 125.000 | -564.464 | 0.0 | 51.9 | FLY |
| F015-H | 6 | -1715.588 | 125.000 | -563.636 | 0.0 | 71.1 | FLY |
| F015-S | 6 | -1724.353 | 125.000 | -563.746 | 0.0 | 86.1 | FLY |
| F016-H | 6 | -1723.323 | 60.000 | -564.442 | 0.0 | 22.8 | no |
| F016-S | 6 | -1816.336 | 60.000 | -564.415 | 90.0 | 31.2 | m/b |
| F017-H | 6 | -1718.772 | 60.000 | -564.155 | 0.0 | 47.7 | no |
| F017-S | 6 | -1709.330 | 123.000 | -563.812 | 0.0 | 63.6 | FLY |
| F018-H | 6 | -1726.355 | 69.000 | -564.440 | 0.0 | 48.0 | FLY |
| F018-S | 6 | -1718.929 | 125.000 | -564.159 | 0.0 | 24.6 | FLY |
| F019-H | 6 | -1715.615 | 95.000 | -563.485 | 0.0 | 71.7 | FLY |
| F019-S | 6 | -1705.242 | 80.000 | -563.984 | 0.0 | 94.5 | FLY |
| F020-H | 6 | -1734.481 | 125.000 | -564.333 | 0.0 | 49.8 | FLY |
| F020-S | 6 | -1727.742 | 125.000 | -564.412 | 0.0 | 36.3 | FLY |
| F021-H | 6 | -1722.296 | 125.000 | -564.168 | 0.0 | 82.8 | FLY |
| F021-S | 6 | -1713.607 | 125.000 | -563.149 | 0.0 | 86.4 | FLY |
| F022-H | 6 | -1820.705 | 60.000 | -563.313 | 0.0 | 80.4 | no |
| F022-S | 6 | -1816.345 | 60.000 | -563.491 | 0.0 | 62.4 | no |
| F023-H | 6 | -1717.944 | 125.000 | -564.067 | 0.0 | 54.3 | FLY |
| F023-S | 6 | -1702.224 | 125.000 | -563.226 | 0.0 | 91.2 | FLY |
| F024-H | 6 | -1715.125 | 75.000 | -564.400 | 0.0 | 46.5 | FLY |
| F024-S | 6 | -1725.472 | 119.000 | -564.189 | 0.0 | 19.8 | FLY |
| F025-H | 6 | -1712.891 | 99.000 | -563.741 | 0.0 | 53.1 | FLY |
| F025-S | 6 | -1710.020 | 125.000 | -563.794 | 0.0 | 72.0 | FLY |
| F026-H | 6 | -1721.010 | 125.000 | -564.459 | 0.0 | 76.2 | FLY |
| F026-S | 6 | -1724.898 | 125.000 | -564.321 | 0.0 | 58.5 | FLY |
| F027-H | 6 | -1721.536 | 93.000 | -564.402 | 0.0 | 40.2 | FLY |
| F027-S | 6 | -1718.829 | 125.000 | -564.175 | 0.0 | 90.3 | FLY |
| F028-H | 6 | -1822.790 | 60.000 | -564.277 | 90.0 | 45.0 | m/b |
| F028-S | 6 | -1721.798 | 125.000 | -563.750 | 0.0 | 64.2 | FLY |
| F029-H | 6 | -1733.686 | 85.000 | -564.115 | 0.0 | 46.5 | FLY |
| F029-S | 6 | -1721.526 | 125.000 | -564.072 | 0.0 | 57.6 | FLY |
| F030-H | 6 | -1715.168 | 125.000 | -564.192 | 0.0 | 68.7 | FLY |
| F030-S | 6 | -1702.828 | 121.000 | -564.042 | 0.0 | 51.0 | FLY |
| F031-H | 6 | -1733.853 | 75.000 | -564.005 | 0.0 | 43.2 | FLY |
| F031-S | 6 | -1726.303 | 126.000 | -563.635 | 0.0 | 70.5 | FLY |
| F032-H | 6 | -1731.491 | 69.000 | -563.796 | 0.0 | 76.2 | FLY |
| F032-S | 6 | -1732.960 | 125.000 | -563.958 | 0.0 | 54.0 | FLY |
| F033-H | 6 | -1722.097 | 108.000 | -564.402 | 0.0 | 110.1 | FLY |
| F033-S | 6 | -1824.168 | 60.000 | -563.350 | 0.0 | 112.2 | no |
| F034-H | 6 | -1713.156 | 67.000 | -563.846 | 0.0 | 67.8 | FLY |
| F034-S | 6 | -1825.294 | 60.000 | -564.137 | 72.0 | 62.1 | m/b |
| F035-H | 6 | -1815.669 | 60.000 | -564.486 | 90.0 | 36.0 | m/b |
| F035-S | 6 | -1714.367 | 121.000 | -564.262 | 0.0 | 44.4 | FLY |
| F036-H | 6 | -1728.362 | 125.000 | -564.399 | 0.0 | 38.1 | FLY |
| F036-S | 6 | -1823.045 | 60.000 | -564.301 | 0.0 | 29.1 | no |
| F037-H | 6 | -1726.049 | 125.000 | -564.217 | 0.0 | 61.5 | FLY |

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|---|---|---|---|---|---|---|---|
| F037-S | 6 | -1711.864 | 115.000 | -563.791 | 0.0 | 82.2 | FLY |
| F038-H | 6 | -1814.426 | 60.000 | -564.432 | 90.0 | 56.7 | m/b |
| F038-S | 6 | -1718.779 | 60.000 | -563.996 | 0.0 | 42.3 | no |
| F040-H | 6 | -1741.465 | 97.000 | -564.128 | 0.0 | 49.8 | FLY |
| F040-S | 6 | -1821.642 | 60.000 | -564.373 | 0.0 | 32.1 | no |
| F041-H | 6 | -1813.961 | 60.000 | -564.307 | 0.0 | 41.1 | no |
| F041-S | 6 | -1710.037 | 60.000 | -564.326 | 0.0 | 56.7 | no |
| F042-H | 6 | -1726.825 | 60.000 | -564.380 | 0.0 | 57.3 | no |
| F042-S | 6 | -1815.737 | 60.000 | -564.259 | 0.0 | 47.1 | no |
| F043-H | 6 | -1819.728 | 60.000 | -564.443 | 0.0 | 14.1 | no |
| F043-S | 6 | -1823.886 | 60.000 | -564.241 | 0.0 | 50.4 | no |
| H001-H | 6 | -1715.716 | 65.000 | -563.886 | 0.0 | 63.3 | FLY |
| H002-H | 6 | -1704.758 | 60.000 | -563.924 | 0.0 | 44.7 | no |
| H003-H | 6 | -1695.686 | 125.000 | -563.784 | 0.0 | 55.8 | FLY |
| I001-H | 6 | -1721.600 | 73.000 | -563.921 | 0.0 | 63.0 | FLY |
| I001-S | 6 | -1820.139 | 60.000 | -563.871 | 0.0 | 62.4 | no |
| P001-H | 6 | -1825.357 | 60.000 | -563.981 | 90.0 | 57.0 | m/b |
| P001-S | 6 | -1727.622 | 80.000 | -563.392 | 0.0 | 75.0 | FLY |
| P002-H | 6 | -1713.279 | 60.000 | -564.475 | 0.0 | 48.9 | no |
| P002-S | 6 | -1712.685 | 250.000 | -564.428 | 0.0 | 44.4 | FLY |
| P003-H | 6 | -1709.365 | 250.000 | -564.027 | 0.0 | 33.0 | FLY |
| P003-S | 6 | -1802.155 | 60.000 | -564.284 | 90.0 | 36.0 | m/b |
| P004-H | 6 | -1726.375 | 200.000 | -563.773 | 0.0 | 56.1 | FLY |
| P004-S | 6 | -1807.776 | 60.000 | -563.815 | 0.0 | 48.9 | no |
| P005-H | 6 | -1719.557 | 244.000 | -564.158 | 0.0 | 32.7 | FLY |
| P005-S | 6 | -1727.854 | 184.000 | -564.022 | 0.0 | 59.4 | FLY |
| P006-H | 6 | -1720.340 | 58.000 | -563.579 | 0.0 | 59.1 | no |
| P006-S | 6 | -1710.604 | 168.000 | -564.049 | 0.0 | 28.5 | FLY |
| P007-H | 6 | -1814.434 | 60.000 | -564.307 | 90.0 | 22.2 | m/b |
| P007-S | 6 | -1715.525 | 234.000 | -563.985 | 0.0 | 44.1 | FLY |
| P008-H | 6 | -1817.505 | 60.000 | -563.843 | 0.0 | 54.6 | no |
| P008-S | 6 | -1804.104 | 60.000 | -564.084 | 0.0 | 83.4 | no |
| P009-H | 6 | -1820.731 | 60.000 | -563.991 | 0.0 | 61.5 | no |
| P009-S | 6 | -1728.856 | 124.000 | -563.630 | 0.0 | 147.9 | FLY |
| P010-H | 6 | -1805.235 | 60.000 | -563.799 | 0.0 | 68.4 | no |
| P010-S | 6 | -1796.315 | 60.000 | -564.456 | 0.0 | 39.9 | no |

## <u>Task Room 7 Reduced Data</u>

| **File** | Room | X | Y | Z | Rotate | Speed | RESULT |
|---|---|---|---|---|---|---|---|
| A001-H | 7 | -1302.256 | 60.000 | -690.515 | 90.0 | 48.0 | ROTATE |
| A002-H | 7 | -1302.519 | 60.000 | -686.951 | 90.0 | 63.0 | ROTATE |
| A003-H | 7 | -1302.438 | 60.000 | -686.521 | 90.0 | 64.8 | ROTATE |
| A004-H | 7 | -1303.364 | 60.000 | -699.370 | 0.0 | 72.6 | no |
| A005-H | 7 | -1303.136 | 60.000 | -693.451 | 90.0 | 66.3 | ROTATE |
| B001-H | 7 | -1302.294 | 60.000 | -698.826 | 0.0 | 13.8 | no |
| B001-S | 7 | -1302.485 | 60.000 | -684.405 | 0.0 | 23.7 | no |
| B002-H | 7 | -1302.978 | 60.000 | -699.535 | 90.0 | 54.9 | ROTATE |
| B002-S | 7 | -1302.361 | 60.000 | -696.355 | 84.0 | 51.6 | ROTATE |
| B003-H | 7 | -1302.917 | 60.000 | -693.633 | 0.0 | 45.3 | no |
| B003-S | 7 | -1302.478 | 60.000 | -690.380 | 0.0 | 54.3 | no |
| B004-H | 7 | -1302.324 | 60.000 | -688.247 | 72.0 | 44.4 | ROTATE |
| B004-S | 7 | -1302.485 | 60.000 | -695.685 | 90.0 | 74.4 | ROTATE |
| B005-H | 7 | -1302.338 | 60.000 | -700.765 | 90.0 | 18.0 | ROTATE |
| B005-S | 7 | -1302.307 | 60.000 | -691.169 | 0.0 | 36.9 | no |
| F001-H | 7 | -1302.678 | 60.000 | -701.028 | 90.0 | 29.4 | ROTATE |
| F001-S | 7 | -1302.647 | 60.000 | -693.209 | 90.0 | 27.3 | ROTATE |
| F002-H | 7 | -1303.239 | 60.000 | -693.176 | 90.0 | 72.9 | ROTATE |
| F002-S | 7 | -1302.320 | 60.000 | -698.457 | 90.0 | 65.7 | ROTATE |
| F003-H | 7 | -1302.457 | 60.000 | -697.123 | 90.0 | 66.9 | ROTATE |

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|---|---|---|---|---|---|---|---|
| F003-S | 7 | -1304.140 | 60.000 | -691.160 | 90.0 | 133.2 | ROTATE |
| F004-H | 7 | -1303.006 | 60.000 | -692.052 | 0.0 | 67.5 | no |
| F004-S | 7 | -1302.927 | 60.000 | -702.097 | 0.0 | 51.0 | no |
| F005-H | 7 | -1302.342 | 60.000 | -689.084 | 90.0 | 81.9 | ROTATE |
| F005-S | 7 | -1304.133 | 60.000 | -691.177 | 90.0 | 115.5 | ROTATE |
| F006-H | 7 | -1302.598 | 60.000 | -696.226 | 87.0 | 78.6 | ROTATE |
| F006-S | 7 | -1302.355 | 60.000 | -695.498 | 90.0 | 66.9 | ROTATE |
| F007-H | 7 | -1302.380 | 60.000 | -692.052 | 90.0 | 27.3 | ROTATE |
| F007-S | 7 | -1302.387 | 60.000 | -688.019 | 90.0 | 45.0 | ROTATE |
| F008-H | 7 | -1302.353 | 60.000 | -688.159 | 90.0 | 23.1 | ROTATE |
| F008-S | 7 | -1302.583 | 60.000 | -692.209 | 51.0 | 35.1 | ROTATE |
| F009-H | 7 | -1302.563 | 60.000 | -694.968 | 90.0 | 74.4 | ROTATE |
| F009-S | 7 | -1302.468 | 60.000 | -690.378 | 27.0 | 146.1 | ROTATE |
| F010-H | 7 | -1303.093 | 60.000 | -699.043 | 90.0 | 68.7 | ROTATE |
| F010-S | 7 | -1302.447 | 60.000 | -698.503 | 90.0 | 36.3 | ROTATE |
| F011-H | 7 | -1302.508 | 60.000 | -696.864 | 90.0 | 19.8 | ROTATE |
| F011-S | 7 | -1302.507 | 60.000 | -699.515 | 90.0 | 32.4 | ROTATE |
| F012-H | 7 | -1302.721 | 60.000 | -690.763 | 0.0 | 65.4 | no |
| F012-S | 7 | -1302.448 | 60.000 | -686.362 | 0.0 | 52.8 | no |
| F013-H | 7 | -1302.477 | 60.000 | -697.044 | 90.0 | 66.3 | ROTATE |
| F013-S | 7 | -1303.497 | 60.000 | -694.904 | 0.0 | 124.8 | no |
| F014-H | 7 | -1302.313 | 60.000 | -691.819 | 81.0 | 45.0 | ROTATE |
| F014-S | 7 | -1302.328 | 60.000 | -697.499 | 66.0 | 58.5 | ROTATE |
| F015-H | 7 | -1302.520 | 60.000 | -696.143 | 90.0 | 57.0 | ROTATE |
| F015-S | 7 | -1302.609 | 60.000 | -696.453 | 90.0 | 60.3 | ROTATE |
| F016-H | 7 | -1302.532 | 60.000 | -697.161 | 90.0 | 18.6 | ROTATE |
| F016-S | 7 | -1302.881 | 60.000 | -702.530 | 90.0 | 45.9 | ROTATE |
| F017-H | 7 | -1302.448 | 60.000 | -702.657 | 90.0 | 38.4 | ROTATE |
| F017-S | 7 | -1302.754 | 60.000 | -695.017 | 93.0 | 56.1 | ROTATE |
| F018-H | 7 | -1302.488 | 60.000 | -697.525 | 90.0 | 45.3 | ROTATE |
| F018-S | 7 | -1302.404 | 60.000 | -697.328 | 90.0 | 28.8 | ROTATE |
| F019-H | 7 | -1302.544 | 60.000 | -692.862 | 90.0 | 35.7 | ROTATE |
| F019-S | 7 | -1303.043 | 60.000 | -692.769 | 90.0 | 82.5 | ROTATE |
| F020-H | 7 | -1302.448 | 60.000 | -690.188 | 90.0 | 57.6 | ROTATE |
| F020-S | 7 | -1302.743 | 60.000 | -689.035 | 90.0 | 46.5 | ROTATE |
| F021-H | 7 | -1302.363 | 60.000 | -697.259 | 90.0 | 66.6 | ROTATE |
| F021-S | 7 | -1302.875 | 60.000 | -691.862 | 93.0 | 56.4 | ROTATE |
| F022-H | 7 | -1302.409 | 60.000 | -698.458 | 90.0 | 63.3 | ROTATE |
| F022-S | 7 | -1303.088 | 60.000 | -699.479 | 63.0 | 75.6 | ROTATE |
| F023-H | 7 | -1302.808 | 60.000 | -697.569 | 0.0 | 50.1 | no |
| F023-S | 7 | -1303.029 | 60.000 | -692.098 | 15.0 | 84.6 | no |
| F024-H | 7 | -1302.906 | 60.000 | -694.995 | 72.0 | 42.9 | ROTATE |
| F024-S | 7 | -1302.251 | 60.000 | -697.451 | 90.0 | 23.4 | ROTATE |
| F025-H | 7 | -1302.426 | 60.000 | -697.899 | 90.0 | 54.0 | ROTATE |
| F025-S | 7 | -1302.734 | 60.000 | -694.588 | 90.0 | 66.3 | ROTATE |
| F026-H | 7 | -1302.892 | 60.000 | -690.065 | 90.0 | 80.4 | ROTATE |
| F026-S | 7 | -1302.758 | 60.000 | -688.310 | 90.0 | 64.2 | ROTATE |
| F027-H | 7 | -1302.451 | 60.000 | -695.894 | 90.0 | 48.9 | ROTATE |
| F027-S | 7 | -1302.962 | 60.000 | -688.248 | 0.0 | 83.4 | no |
| F028-H | 7 | -1303.500 | 60.000 | -694.946 | 90.0 | 87.6 | ROTATE |
| F028-S | 7 | -1302.824 | 60.000 | -697.098 | 90.0 | 42.6 | ROTATE |
| F029-H | 7 | -1302.636 | 60.000 | -691.998 | 90.0 | 43.2 | ROTATE |
| F029-S | 7 | -1302.617 | 60.000 | -691.436 | 90.0 | 28.2 | ROTATE |
| F030-H | 7 | -1302.372 | 60.000 | -683.576 | 90.0 | 58.2 | ROTATE |
| F030-S | 7 | -1302.736 | 60.000 | -689.949 | 90.0 | 54.0 | ROTATE |
| F031-H | 7 | -1302.771 | 60.000 | -693.464 | 42.0 | 37.5 | ROTATE |
| F031-S | 7 | -1302.695 | 60.000 | -683.866 | 45.0 | 74.7 | ROTATE |
| F032-H | 7 | -1302.991 | 60.000 | -692.400 | 0.0 | 86.7 | no |
| F032-S | 7 | -1302.879 | 60.000 | -692.747 | 90.0 | 43.5 | ROTATE |
| F033-H | 7 | -1303.082 | 60.000 | -692.556 | 90.0 | 87.6 | ROTATE |

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|---|---|---|---|---|---|---|---|
| F033-S | 7 | -1302.866 | 60.000 | -692.544 | 0.0 | 118.2 | no |
| F034-H | 7 | -1302.555 | 60.000 | -699.031 | 3.0 | 72.3 | no |
| F034-S | 7 | -1302.620 | 60.000 | -702.376 | 39.0 | 75.9 | ROTATE |
| F035-H | 7 | -1302.385 | 60.000 | -687.519 | 90.0 | 33.9 | ROTATE |
| F035-S | 7 | -1302.404 | 60.000 | -693.537 | 90.0 | 37.5 | ROTATE |
| F036-H | 7 | -1302.564 | 60.000 | -682.993 | 90.0 | 29.1 | ROTATE |
| F036-S | 7 | -1302.330 | 60.000 | -690.687 | 0.0 | 18.3 | no |
| F037-H | 7 | -1302.347 | 60.000 | -697.996 | 90.0 | 51.9 | ROTATE |
| F037-S | 7 | -1303.213 | 60.000 | -692.275 | 90.0 | 78.6 | ROTATE |
| F038-H | 7 | -1302.387 | 60.000 | -699.895 | 90.0 | 66.3 | ROTATE |
| F038-S | 7 | -1302.829 | 60.000 | -699.421 | 90.0 | 42.9 | ROTATE |
| F040-H | 7 | -1302.851 | 60.000 | -693.354 | 90.0 | 45.3 | ROTATE |
| F040-S | 7 | -1302.470 | 60.000 | -693.070 | 90.0 | 43.2 | ROTATE |
| F041-H | 7 | -1302.327 | 60.000 | -698.095 | 0.0 | 13.8 | no |
| F041-S | 7 | -1302.562 | 60.000 | -698.125 | 0.0 | 31.2 | no |
| F042-H | 7 | -1302.554 | 60.000 | -701.939 | 90.0 | 21.0 | ROTATE |
| F042-S | 7 | -1302.453 | 60.000 | -698.332 | 0.0 | 26.7 | no |
| F043-H | 7 | -1302.357 | 60.000 | -693.735 | 0.0 | 19.5 | no |
| F043-S | 7 | -1302.258 | 60.000 | -696.535 | 12.0 | 42.3 | no |
| H001-H | 7 | -1302.285 | 60.000 | -701.336 | 0.0 | 18.3 | no |
| H002-H | 7 | -1302.591 | 60.000 | -696.658 | 0.0 | 36.3 | no |
| H003-H | 7 | -1303.026 | 60.000 | -695.025 | 3.0 | 63.6 | no |
| I001-H | 7 | -1302.812 | 60.000 | -699.723 | 90.0 | 60.0 | ROTATE |
| I001-S | 7 | -1302.638 | 60.000 | -700.140 | 90.0 | 30.0 | ROTATE |
| P001-H | 7 | -1302.277 | 60.000 | -692.994 | 90.0 | 53.1 | ROTATE |
| P001-S | 7 | -1302.859 | 60.000 | -689.654 | 90.0 | 65.4 | ROTATE |
| P002-H | 7 | -1302.708 | 60.000 | -700.073 | 90.0 | 57.0 | ROTATE |
| P002-S | 7 | -1302.335 | 60.000 | -698.115 | 90.0 | 41.7 | ROTATE |
| P003-H | 7 | -1302.364 | 60.000 | -705.284 | 90.0 | 11.4 | ROTATE |
| P003-S | 7 | -1302.396 | 60.000 | -700.577 | 90.0 | 12.6 | ROTATE |
| P004-H | 7 | -1302.885 | 60.000 | -692.642 | 90.0 | 50.1 | ROTATE |
| P004-S | 7 | -1302.970 | 166.000 | -703.156 | 0.0 | 59.7 | m/b |
| P005-H | 7 | -1302.495 | 60.000 | -692.936 | 90.0 | 16.5 | ROTATE |
| P005-S | 7 | -1302.632 | 60.000 | -696.053 | 72.0 | 27.0 | ROTATE |
| P006-H | 7 | -1302.604 | 60.000 | -694.699 | 0.0 | 67.8 | no |
| P006-S | 7 | -1302.591 | 60.000 | -697.811 | 0.0 | 47.7 | no |
| P007-H | 7 | -1302.732 | 60.000 | -698.714 | 90.0 | 33.0 | ROTATE |
| P007-S | 7 | -1302.927 | 60.000 | -687.158 | 90.0 | 43.5 | ROTATE |
| P008-H | 7 | -1302.909 | 60.000 | -703.070 | 0.0 | 67.5 | no |
| P008-S | 7 | -1302.766 | 60.000 | -704.497 | 0.0 | 66.3 | no |
| P009-H | 7 | -1302.764 | 60.000 | -688.657 | 0.0 | 72.6 | no |
| P009-S | 7 | -1303.013 | 60.000 | -698.841 | 0.0 | 133.5 | no |
| P010-H | 7 | -1302.412 | 60.000 | -694.597 | 90.0 | 60.6 | ROTATE |
| P010-S | 7 | -1303.038 | 60.000 | -704.687 | 0.0 | 60.9 | no |

## Task Room 8 Reduced Data

| File | Room | X | Y | Z | Rotate | Speed | RESULT |
|---|---|---|---|---|---|---|---|
| A001-H | 8 | -1222.322 | 60.000 | -222.158 | 0.0 | 40.5 | not |
| A002-H | 8 | -1237.414 | 60.000 | -222.360 | 0.0 | 69.9 | not |
| A003-H | 8 | -1237.935 | 60.000 | -222.105 | 0.0 | 62.4 | not |
| A004-H | 8 | -1108.885 | 60.000 | -221.753 | 0.0 | 69.6 | CATCH |
| A005-H | 8 | -1222.695 | 60.000 | -222.272 | 0.0 | 58.5 | not |
| B001-H | 8 | -1125.904 | 60.000 | -221.509 | 0.0 | 17.1 | CATCH |
| B001-S | 8 | -1230.500 | 60.000 | -221.964 | 0.0 | 46.8 | not |
| B002-H | 8 | -1114.823 | 60.000 | -221.852 | 0.0 | 23.7 | CATCH |
| B002-S | 8 | -1232.286 | 60.000 | -222.294 | 0.0 | 84.9 | not |
| B003-H | 8 | -1104.294 | 60.000 | -221.894 | 0.0 | 49.2 | CATCH |
| B003-S | 8 | -1236.751 | 60.000 | -221.951 | 0.0 | 58.5 | not |
| B004-H | 8 | -1109.724 | 60.000 | -222.652 | 0.0 | 69.9 | CATCH |

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|---|---|---|---|---|---|---|---|
| B004-S | 8 | -1234.119 | 60.000 | -221.890 | 0.0 | 94.8 | not |
| B005-H | 8 | -1110.643 | 60.000 | -221.506 | 90.0 | 24.6 | CATCH |
| B005-S | 8 | -1189.553 | 60.000 | -221.755 | 0.0 | 16.5 | not |
| F001-H | 8 | -1232.963 | 60.000 | -221.677 | 0.0 | 36.3 | not |
| F001-S | 8 | -1234.633 | 60.000 | -222.083 | 0.0 | 43.5 | not |
| F002-H | 8 | -1107.128 | 60.000 | -221.993 | 0.0 | 83.1 | CATCH |
| F002-S | 8 | -1124.218 | 60.000 | -221.521 | 0.0 | 71.4 | CATCH |
| F003-H | 8 | -1114.487 | 60.000 | -221.568 | 0.0 | 63.0 | CATCH |
| F003-S | 8 | -1134.246 | 60.000 | -222.127 | 0.0 | 143.1 | CATCH |
| F004-H | 8 | -1127.115 | 60.000 | -221.977 | 0.0 | 81.6 | CATCH |
| F004-S | 8 | -1104.123 | 60.000 | -222.087 | 0.0 | 41.4 | CATCH |
| F005-H | 8 | -1123.300 | 60.000 | -221.675 | 0.0 | 113.4 | CATCH |
| F005-S | 8 | -1128.503 | 80.000 | -222.571 | 0.0 | 119.7 | CATCH |
| F006-H | 8 | -1115.859 | 60.000 | -221.626 | 0.0 | 84.6 | CATCH |
| F006-S | 8 | -1228.468 | 60.000 | -222.711 | 0.0 | 83.4 | not |
| F007-H | 8 | -1229.778 | 60.000 | -221.971 | 0.0 | 55.2 | not |
| F007-S | 8 | -1229.450 | 60.000 | -222.071 | 0.0 | 65.4 | not |
| F008-H | 8 | -1240.681 | 60.000 | -221.755 | 0.0 | 34.5 | not |
| F008-S | 8 | -1234.828 | 60.000 | -222.144 | 0.0 | 42.6 | not |
| F009-H | 8 | -1227.534 | 60.000 | -221.763 | 90.0 | 59.7 | not |
| F009-S | 8 | -1226.720 | 60.000 | -221.707 | 45.0 | 149.4 | not |
| F010-H | 8 | -1225.429 | 60.000 | -221.796 | 0.0 | 87.0 | not |
| F010-S | 8 | -1126.281 | 60.000 | -221.737 | 0.0 | 48.6 | CATCH |
| F011-H | 8 | -1230.659 | 60.000 | -221.865 | 0.0 | 23.4 | not |
| F011-S | 8 | -1232.104 | 60.000 | -222.222 | 0.0 | 48.3 | not |
| F012-H | 8 | -1231.782 | 60.000 | -221.607 | 0.0 | 75.6 | not |
| F012-S | 8 | -1229.060 | 60.000 | -222.131 | 0.0 | 54.3 | not |
| F013-H | 8 | -1224.597 | 60.000 | -222.482 | 0.0 | 77.1 | not |
| F013-S | 8 | -1227.180 | 60.000 | -222.887 | 0.0 | 111.3 | not |
| F014-H | 8 | -1231.017 | 60.000 | -222.044 | 0.0 | 71.4 | not |
| F014-S | 8 | -1226.003 | 60.000 | -221.654 | 0.0 | 60.9 | not |
| F015-H | 8 | -1236.898 | 60.000 | -222.109 | 0.0 | 36.9 | not |
| F015-S | 8 | -1231.898 | 60.000 | -221.769 | 0.0 | 67.5 | not |
| F016-H | 8 | -1106.534 | 60.000 | -221.778 | 90.0 | 17.1 | CATCH |
| F016-S | 8 | -1122.342 | 60.000 | -222.581 | 90.0 | 70.8 | CATCH |
| F017-H | 8 | -1227.276 | 60.000 | -221.982 | 0.0 | 38.4 | not |
| F017-S | 8 | -1227.994 | 60.000 | -222.072 | 0.0 | 51.6 | not |
| F018-H | 8 | -1225.619 | 60.000 | -221.612 | 0.0 | 50.4 | not |
| F018-S | 8 | -1226.025 | 60.000 | -221.995 | 0.0 | 40.5 | not |
| F019-H | 8 | -1231.891 | 60.000 | -222.148 | 90.0 | 58.5 | not |
| F019-S | 8 | -1232.199 | 60.000 | -221.799 | 0.0 | 92.4 | not |
| F020-H | 8 | -1231.399 | 60.000 | -221.871 | 0.0 | 70.5 | not |
| F020-S | 8 | -1235.734 | 60.000 | -221.832 | 0.0 | 51.9 | not |
| F021-H | 8 | -1224.602 | 60.000 | -222.015 | 0.0 | 58.8 | not |
| F021-S | 8 | -1233.768 | 60.000 | -222.295 | 0.0 | 83.1 | not |
| F022-H | 8 | -1114.582 | 60.000 | -222.216 | 0.0 | 78.0 | CATCH |
| F022-S | 8 | -1221.829 | 60.000 | -221.804 | 0.0 | 63.6 | not |
| F023-H | 8 | -1232.122 | 60.000 | -221.639 | 0.0 | 36.6 | not |
| F023-S | 8 | -1226.170 | 60.000 | -222.316 | 0.0 | 81.9 | not |
| F024-H | 8 | -1227.912 | 60.000 | -222.219 | 90.0 | 44.4 | not |
| F024-S | 8 | -1228.462 | 60.000 | -221.722 | 0.0 | 25.8 | not |
| F025-H | 8 | -1232.206 | 60.000 | -221.971 | 0.0 | 60.6 | not |
| F025-S | 8 | -1236.593 | 60.000 | -221.529 | 0.0 | 64.5 | not |
| F026-H | 8 | -1229.287 | 60.000 | -222.002 | 0.0 | 59.7 | not |
| F026-S | 8 | -1237.517 | 60.000 | -221.540 | 0.0 | 63.9 | not |
| F027-H | 8 | -1228.134 | 60.000 | -222.049 | 0.0 | 75.3 | not |
| F027-S | 8 | -1227.929 | 60.000 | -221.635 | 0.0 | 97.8 | not |
| F028-H | 8 | -1225.830 | 60.000 | -221.687 | 0.0 | 62.7 | not |
| F028-S | 8 | -1232.440 | 60.000 | -221.979 | 0.0 | 104.1 | not |
| F029-H | 8 | -1226.443 | 60.000 | -222.229 | 0.0 | 67.5 | not |

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|---|---|---|---|---|---|---|---|
| F029-S | 8 | -1239.917 | 60.000 | -221.763 | 0.0 | 34.8 | not |
| F030-H | 8 | -1233.717 | 60.000 | -222.290 | 0.0 | 60.6 | not |
| F030-S | 8 | -1232.720 | 60.000 | -222.178 | 0.0 | 59.7 | not |
| F031-H | 8 | -1228.801 | 60.000 | -221.681 | 0.0 | 40.5 | not |
| F031-S | 8 | -1229.314 | 60.000 | -222.178 | 0.0 | 47.7 | not |
| F032-H | 8 | -1227.243 | 60.000 | -221.969 | 0.0 | 85.8 | not |
| F032-S | 8 | -1225.659 | 60.000 | -222.396 | 0.0 | 74.7 | not |
| F033-H | 8 | -1223.164 | 60.000 | -222.587 | 0.0 | 84.3 | not |
| F033-S | 8 | -1216.124 | 60.000 | -223.143 | 0.0 | 125.4 | not |
| F034-H | 8 | -1230.210 | 60.000 | -221.582 | 0.0 | 75.6 | not |
| F034-S | 8 | -1233.165 | 60.000 | -222.425 | 0.0 | 91.5 | not |
| F035-H | 8 | -1234.782 | 60.000 | -222.085 | 90.0 | 44.4 | not |
| F035-S | 8 | -1231.470 | 60.000 | -221.956 | 0.0 | 59.7 | not |
| F036-H | 8 | -1231.400 | 60.000 | -221.825 | 0.0 | 29.7 | not |
| F036-S | 8 | -1229.233 | 60.000 | -221.736 | 0.0 | 20.1 | not |
| F037-H | 8 | -1228.427 | 60.000 | -222.033 | 0.0 | 57.0 | not |
| F037-S | 8 | -1228.938 | 60.000 | -222.015 | 0.0 | 70.5 | not |
| F038-H | 8 | -1205.407 | 60.000 | -222.291 | 0.0 | 74.4 | not |
| F038-S | 8 | -1198.293 | 60.000 | -222.116 | 0.0 | 49.2 | not |
| F040-H | 8 | -1225.564 | 60.000 | -221.845 | 0.0 | 54.9 | not |
| F040-S | 8 | -1232.721 | 60.000 | -221.526 | 0.0 | 36.6 | not |
| F041-H | 8 | -1102.758 | 60.000 | -221.677 | 0.0 | 14.7 | CATCH |
| F041-S | 8 | -1102.864 | 60.000 | -221.848 | 0.0 | 21.3 | CATCH |
| F042-H | 8 | -1227.092 | 60.000 | -221.714 | 0.0 | 35.4 | not |
| F042-S | 8 | -1229.351 | 60.000 | -222.121 | 0.0 | 44.4 | not |
| F043-H | 8 | -1233.970 | 60.000 | -221.717 | 0.0 | 29.4 | not |
| F043-S | 8 | -1236.783 | 60.000 | -222.225 | 0.0 | 44.4 | not |
| H001-H | 8 | -1228.337 | 60.000 | -221.541 | 0.0 | 55.8 | not |
| H002-H | 8 | -1228.252 | 60.000 | -221.692 | 0.0 | 21.0 | not |
| H003-H | 8 | -1227.286 | 60.000 | -221.520 | 0.0 | 53.7 | not |
| I001-H | 8 | -1227.235 | 60.000 | -221.706 | 0.0 | 65.4 | not |
| I001-S | 8 | -1227.575 | 60.000 | -222.148 | 0.0 | 63.3 | not |
| P001-H | 8 | -1220.750 | 60.000 | -222.577 | 0.0 | 81.3 | not |
| P001-S | 8 | -1232.298 | 60.000 | -222.561 | 0.0 | 72.3 | not |
| P002-H | 8 | -1231.289 | 60.000 | -221.570 | 0.0 | 61.8 | not |
| P002-S | 8 | -1240.823 | 60.000 | -222.174 | 0.0 | 40.2 | not |
| P003-H | 8 | -1192.135 | 60.000 | -221.561 | 0.0 | 10.5 | not |
| P003-S | 8 | -1203.645 | 60.000 | -221.758 | 0.0 | 30.6 | not |
| P004-H | 8 | -1225.416 | 60.000 | -221.546 | 90.0 | 41.4 | not |
| P004-S | 8 | -1205.090 | 60.000 | -222.059 | 0.0 | 49.2 | not |
| P005-H | 8 | -1229.771 | 60.000 | -221.618 | 90.0 | 49.2 | not |
| P005-S | 8 | -1223.905 | 60.000 | -221.626 | 90.0 | 20.7 | not |
| P006-H | 8 | -1231.797 | 60.000 | -221.744 | 0.0 | 29.4 | not |
| P006-S | 8 | -1240.880 | 60.000 | -221.513 | 0.0 | 88.5 | not |
| P007-H | 8 | -1233.342 | 60.000 | -221.804 | 0.0 | 30.3 | not |
| P007-S | 8 | -1239.963 | 60.000 | -221.951 | 0.0 | 35.1 | not |
| P008-H | 8 | -1103.411 | 60.000 | -222.104 | 0.0 | 62.4 | CATCH |
| P008-S | 8 | -1180.223 | 60.000 | -221.652 | 18.0 | 46.5 | not |
| P009-H | 8 | -1226.964 | 60.000 | -222.337 | 0.0 | 77.7 | not |
| P009-S | 8 | -1241.475 | 60.000 | -222.883 | 0.0 | 139.2 | not |
| P010-H | 8 | -1110.611 | 60.000 | -221.873 | 0.0 | 61.8 | CATCH |
| P010-S | 8 | -1192.090 | 60.000 | -221.577 | 0.0 | 41.7 | not |

## Task Room 9 Reduced Data

| File | Room | X | Y | Z | Rotate | Speed | RESULT |
|---|---|---|---|---|---|---|---|
| A001-H | 9 | -713.421 | 60.000 | -31.683 | 0.0 | 47.1 | no |
| A002-H | 9 | -714.268 | 60.000 | -32.535 | 0.0 | 94.5 | no |
| A003-H | 9 | -713.307 | 60.000 | -26.338 | 0.0 | 45.3 | no |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| A004-H | 9 | -713.442 | 60.000 | -30.050 | 0.0 | 46.8 | no |
| A005-H | 9 | -713.659 | 125.000 | -116.670 | 0.0 | 68.1 | FLY |
| B001-H | 9 | -712.976 | 60.000 | -27.857 | 0.0 | 17.4 | no |
| B001-S | 9 | -712.771 | 60.000 | -23.528 | 0.0 | 22.2 | no |
| B002-H | 9 | -713.538 | 60.000 | -34.647 | 0.0 | 50.1 | no |
| B002-S | 9 | -712.862 | 60.000 | -15.344 | 0.0 | 76.5 | no |
| B003-H | 9 | -713.446 | 60.000 | -28.665 | 0.0 | 58.8 | no |
| B003-S | 9 | -712.937 | 60.000 | -24.654 | 0.0 | 71.1 | no |
| B004-H | 9 | -713.145 | 60.000 | -33.085 | 0.0 | 50.4 | no |
| B004-S | 9 | -714.291 | 125.000 | -129.016 | 0.0 | 97.8 | FLY |
| B005-H | 9 | -713.121 | 60.000 | -37.704 | 90.0 | 27.3 | m/b |
| B005-S | 9 | -713.240 | 60.000 | -35.115 | 0.0 | 33.9 | no |
| F001-H | 9 | -712.945 | 60.000 | -27.814 | 0.0 | 25.8 | no |
| F001-S | 9 | -713.018 | 60.000 | -15.159 | 0.0 | 51.0 | no |
| F002-H | 9 | -712.757 | 125.000 | -131.850 | 0.0 | 86.4 | FLY |
| F002-S | 9 | -713.238 | 60.000 | -36.774 | 0.0 | 51.9 | no |
| F003-H | 9 | -712.993 | 125.000 | -134.107 | 0.0 | 83.4 | FLY |
| F003-S | 9 | -714.922 | 125.000 | -121.442 | 0.0 | 133.8 | FLY |
| F004-H | 9 | -713.411 | 60.000 | -39.952 | 0.0 | 80.1 | no |
| F004-S | 9 | -713.572 | 60.000 | -37.100 | 0.0 | 71.7 | no |
| F005-H | 9 | -714.904 | 125.000 | -140.604 | 0.0 | 150.0 | FLY |
| F005-S | 9 | -712.883 | 125.000 | -127.571 | 0.0 | 115.2 | FLY |
| F006-H | 9 | -712.916 | 107.000 | -139.820 | 0.0 | 83.1 | FLY |
| F006-S | 9 | -713.601 | 60.000 | -23.187 | 0.0 | 66.3 | no |
| F007-H | 9 | -712.936 | 125.000 | -126.980 | 0.0 | 65.7 | FLY |
| F007-S | 9 | -713.094 | 60.000 | -26.089 | 0.0 | 60.3 | no |
| F008-H | 9 | -713.276 | 125.000 | -122.856 | 0.0 | 32.1 | FLY |
| F008-S | 9 | -712.861 | 125.000 | -123.512 | 0.0 | 36.9 | FLY |
| F009-H | 9 | -713.935 | 125.000 | -132.924 | 0.0 | 80.4 | FLY |
| F009-S | 9 | -715.072 | 60.000 | -15.161 | 0.0 | 150.0 | no |
| F010-H | 9 | -713.980 | 108.000 | -135.022 | 18.0 | 95.7 | FLY |
| F010-S | 9 | -713.570 | 60.000 | -27.317 | 0.0 | 51.9 | no |
| F011-H | 9 | -712.800 | 60.000 | -35.156 | 0.0 | 33.0 | no |
| F011-S | 9 | -713.399 | 60.000 | -39.375 | 0.0 | 42.6 | no |
| F012-H | 9 | -713.473 | 111.000 | -121.356 | 0.0 | 75.9 | FLY |
| F012-S | 9 | -713.117 | 125.000 | -118.962 | 0.0 | 76.8 | FLY |
| F013-H | 9 | -713.060 | 60.000 | -25.021 | 0.0 | 79.2 | no |
| F013-S | 9 | -713.672 | 60.000 | -15.692 | 0.0 | 119.1 | no |
| F014-H | 9 | -713.671 | 60.000 | -30.650 | 0.0 | 65.4 | no |
| F014-S | 9 | -713.375 | 125.000 | -124.481 | 0.0 | 62.4 | FLY |
| F015-H | 9 | -714.027 | 60.000 | -33.605 | 0.0 | 81.9 | no |
| F015-S | 9 | -713.114 | 125.000 | -125.027 | 0.0 | 110.4 | FLY |
| F016-H | 9 | -712.907 | 125.000 | -125.551 | 0.0 | 27.3 | FLY |
| F016-S | 9 | -712.758 | 125.000 | -134.543 | 0.0 | 21.3 | FLY |
| F017-H | 9 | -713.287 | 101.000 | -136.388 | 0.0 | 48.0 | FLY |
| F017-S | 9 | -713.470 | 125.000 | -121.446 | 0.0 | 75.6 | FLY |
| F018-H | 9 | -712.793 | 125.000 | -128.357 | 0.0 | 53.1 | FLY |
| F018-S | 9 | -713.064 | 125.000 | -130.434 | 0.0 | 39.9 | FLY |
| F019-H | 9 | -713.115 | 125.000 | -135.168 | 0.0 | 76.2 | FLY |
| F019-S | 9 | -712.849 | 125.000 | -135.563 | 0.0 | 96.0 | FLY |
| F020-H | 9 | -713.638 | 125.000 | -120.567 | 0.0 | 69.6 | FLY |
| F020-S | 9 | -713.329 | 125.000 | -124.170 | 0.0 | 66.3 | FLY |
| F021-H | 9 | -713.149 | 125.000 | -130.581 | 0.0 | 70.2 | FLY |
| F021-S | 9 | -712.888 | 125.000 | -117.342 | 0.0 | 90.9 | FLY |
| F022-H | 9 | -712.938 | 60.000 | -28.485 | 0.0 | 79.5 | no |
| F022-S | 9 | -713.165 | 114.000 | -124.802 | 0.0 | 64.2 | FLY |
| F023-H | 9 | -712.945 | 125.000 | -113.504 | 0.0 | 44.1 | FLY |
| F023-S | 9 | -713.787 | 125.000 | -128.980 | 0.0 | 88.5 | FLY |
| F024-H | 9 | -713.110 | 60.000 | -15.250 | 0.0 | 42.0 | no |
| F024-S | 9 | -712.760 | 60.000 | -21.158 | 0.0 | 22.2 | no |

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|---|---|---|---|---|---|---|---|
| F025-H | 9 | -713.194 | 60.000 | -24.055 | 0.0 | 57.3 | no |
| F025-S | 9 | -713.613 | 125.000 | -127.104 | 0.0 | 70.5 | FLY |
| F026-H | 9 | -713.082 | 60.000 | -26.398 | 0.0 | 79.8 | no |
| F026-S | 9 | -714.002 | 60.000 | -21.722 | 0.0 | 88.8 | no |
| F027-H | 9 | -713.324 | 60.000 | -30.939 | 0.0 | 74.1 | no |
| F027-S | 9 | -713.802 | 125.000 | -118.611 | 0.0 | 84.0 | FLY |
| F028-H | 9 | -714.080 | 125.000 | -129.503 | 0.0 | 84.9 | FLY |
| F028-S | 9 | -713.781 | 60.000 | -32.000 | 0.0 | 105.0 | no |
| F029-H | 9 | -712.773 | 60.000 | -29.758 | 0.0 | 65.7 | no |
| F029-S | 9 | -712.904 | 60.000 | -29.882 | 0.0 | 31.5 | no |
| F030-H | 9 | -713.567 | 125.000 | -131.594 | 0.0 | 71.1 | FLY |
| F030-S | 9 | -712.836 | 125.000 | -130.659 | 0.0 | 85.2 | FLY |
| F031-H | 9 | -713.094 | 60.000 | -25.974 | 0.0 | 28.2 | no |
| F031-S | 9 | -713.636 | 125.000 | -99.778 | 0.0 | 68.7 | FLY |
| F032-H | 9 | -713.421 | 125.000 | -136.236 | 0.0 | 90.3 | FLY |
| F032-S | 9 | -713.647 | 60.000 | -32.495 | 0.0 | 59.4 | no |
| F033-H | 9 | -713.399 | 60.000 | -22.561 | 0.0 | 93.3 | no |
| F033-S | 9 | -713.895 | 100.000 | -120.822 | 0.0 | 125.1 | FLY |
| F034-H | 9 | -713.903 | 125.000 | -129.768 | 0.0 | 94.2 | FLY |
| F034-S | 9 | -713.509 | 60.000 | -25.860 | 0.0 | 110.4 | no |
| F035-H | 9 | -713.277 | 60.000 | -21.373 | 90.0 | 35.1 | m/b |
| F035-S | 9 | -713.171 | 60.000 | -24.303 | 0.0 | 44.7 | no |
| F036-H | 9 | -713.110 | 125.000 | -125.119 | 0.0 | 41.4 | FLY |
| F036-S | 9 | -713.078 | 125.000 | -126.044 | 0.0 | 31.5 | FLY |
| F037-H | 9 | -713.055 | 125.000 | -133.050 | 0.0 | 62.7 | FLY |
| F037-S | 9 | -713.815 | 60.000 | -22.583 | 0.0 | 87.9 | no |
| F038-H | 9 | -713.053 | 60.000 | -130.972 | 0.0 | 59.4 | no |
| F038-S | 9 | -712.776 | 60.000 | -129.564 | 0.0 | 54.6 | no |
| F040-H | 9 | -712.945 | 125.000 | -121.110 | 0.0 | 46.2 | FLY |
| F040-S | 9 | -712.892 | 125.000 | -122.220 | 0.0 | 44.7 | FLY |
| F041-H | 9 | -713.378 | 60.000 | -134.623 | 0.0 | 43.2 | no |
| F041-S | 9 | -713.288 | 60.000 | -25.541 | 0.0 | 34.5 | no |
| F042-H | 9 | -713.137 | 121.000 | -119.506 | 0.0 | 51.3 | FLY |
| F042-S | 9 | -713.263 | 60.000 | -35.926 | 0.0 | 46.5 | no |
| F043-H | 9 | -713.409 | 125.000 | -134.791 | 0.0 | 40.5 | FLY |
| F043-S | 9 | -713.004 | 125.000 | -125.563 | 0.0 | 57.3 | FLY |
| H001-H | 9 | -712.866 | 60.000 | -22.483 | 0.0 | 56.4 | no |
| H002-H | 9 | -713.162 | 58.000 | -134.255 | 0.0 | 35.1 | no |
| H003-H | 9 | -713.180 | 60.000 | -27.483 | 0.0 | 65.4 | no |
| I001-H | 9 | -713.382 | 87.000 | -127.826 | 0.0 | 43.8 | FLY |
| I001-S | 9 | -712.817 | 60.000 | -118.648 | 0.0 | 50.7 | no |
| P001-H | 9 | -713.068 | 180.000 | -137.861 | 0.0 | 64.2 | FLY |
| P001-S | 9 | -712.821 | 60.000 | -28.273 | 0.0 | 60.3 | no |
| P002-H | 9 | -712.921 | 60.000 | -47.393 | 0.0 | 39.0 | no |
| P002-S | 9 | -713.340 | 60.000 | -36.014 | 0.0 | 39.9 | no |
| P003-H | 9 | -712.904 | 60.000 | -39.264 | 0.0 | 19.5 | no |
| P003-S | 9 | -712.820 | 60.000 | -16.205 | 0.0 | 16.2 | no |
| P004-H | 9 | -713.297 | 250.000 | -139.934 | 0.0 | 51.6 | FLY |
| P004-S | 9 | -712.940 | 178.000 | -119.820 | 0.0 | 39.9 | FLY |
| P005-H | 9 | -713.098 | 194.000 | -124.755 | 0.0 | 34.5 | FLY |
| P005-S | 9 | -713.454 | 158.000 | -122.544 | 0.0 | 55.5 | FLY |
| P006-H | 9 | -713.740 | 60.000 | -35.806 | 0.0 | 66.0 | no |
| P006-S | 9 | -713.045 | 74.000 | -116.439 | 0.0 | 49.2 | FLY |
| P007-H | 9 | -713.164 | 60.000 | -40.837 | 90.0 | 30.3 | m/b |
| P007-S | 9 | -713.342 | 208.000 | -133.118 | 0.0 | 48.9 | FLY |
| P008-H | 9 | -712.897 | 60.000 | -36.123 | 0.0 | 97.2 | no |
| P008-S | 9 | -713.133 | 60.000 | -39.492 | 0.0 | 77.7 | no |
| P009-H | 9 | -712.997 | 212.000 | -133.125 | 0.0 | 75.9 | FLY |
| P009-S | 9 | -713.705 | 142.000 | -123.805 | 0.0 | 149.7 | FLY |
| P010-H | 9 | -713.138 | 148.000 | -114.796 | 0.0 | 67.5 | FLY |

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|---|---|---|---|---|---|---|---|
| P010-S | 9 | -713.390 | 60.000 | -39.015 | 0.0 | 47.7 | no |

## Task Room 10 Reduced Data

| File | Room | X | Y | Z | Rotate | Speed | RESULT |
|---|---|---|---|---|---|---|---|
| A001-H | 10 | -593.740 | 60.000 | -564.362 | 0.0 | 48.3 | no |
| A002-H | 10 | -585.676 | 60.000 | -563.805 | 0.0 | 87.0 | no |
| A003-H | 10 | -582.015 | 60.000 | -563.635 | 90.0 | 83.4 | ROTATE |
| A004-H | 10 | -576.342 | 60.000 | -563.356 | 0.0 | 82.5 | no |
| A005-H | 10 | -584.217 | 60.000 | -564.026 | 0.0 | 77.1 | no |
| B001-H | 10 | -569.541 | 60.000 | -564.484 | 0.0 | 14.1 | no |
| B001-S | 10 | -587.383 | 60.000 | -564.350 | 0.0 | 38.4 | no |
| B002-H | 10 | -560.512 | 60.000 | -563.644 | 69.0 | 63.6 | ROTATE |
| B002-S | 10 | -585.833 | 60.000 | -563.587 | 0.0 | 95.7 | no |
| B003-H | 10 | -564.142 | 60.000 | -563.787 | 90.0 | 56.1 | ROTATE |
| B003-S | 10 | -588.496 | 60.000 | -563.913 | 0.0 | 69.6 | no |
| B004-H | 10 | -569.846 | 60.000 | -563.816 | 0.0 | 50.1 | no |
| B004-S | 10 | -587.629 | 60.000 | -563.644 | 0.0 | 83.1 | no |
| B005-H | 10 | -572.276 | 60.000 | -564.411 | 90.0 | 31.5 | ROTATE |
| B005-S | 10 | -584.942 | 60.000 | -564.030 | 0.0 | 53.7 | no |
| F001-H | 10 | -588.262 | 60.000 | -564.484 | 0.0 | 43.5 | no |
| F001-S | 10 | -586.971 | 60.000 | -563.659 | 90.0 | 57.0 | ROTATE |
| F002-H | 10 | -591.456 | 60.000 | -564.091 | 84.0 | 89.4 | ROTATE |
| F002-S | 10 | -586.142 | 60.000 | -563.865 | 0.0 | 61.5 | no |
| F003-H | 10 | -589.032 | 60.000 | -564.048 | 0.0 | 66.6 | no |
| F003-S | 10 | -589.428 | 60.000 | -563.565 | 33.0 | 94.5 | ROTATE |
| F004-H | 10 | -587.214 | 60.000 | -563.573 | 0.0 | 91.5 | no |
| F004-S | 10 | -585.600 | 60.000 | -564.373 | 0.0 | 51.9 | no |
| F005-H | 10 | -588.188 | 60.000 | -563.931 | 0.0 | 54.0 | no |
| F005-S | 10 | -582.601 | 60.000 | -562.982 | 51.0 | 117.6 | ROTATE |
| F006-H | 10 | -591.553 | 60.000 | -563.159 | 0.0 | 86.4 | no |
| F006-S | 10 | -580.861 | 60.000 | -564.293 | 6.0 | 87.0 | no |
| F007-H | 10 | -589.949 | 60.000 | -563.549 | 0.0 | 60.6 | no |
| F007-S | 10 | -589.463 | 60.000 | -563.831 | 0.0 | 63.6 | no |
| F008-H | 10 | -590.268 | 60.000 | -564.027 | 0.0 | 36.6 | no |
| F008-S | 10 | -591.185 | 60.000 | -564.433 | 0.0 | 38.7 | no |
| F009-H | 10 | -588.180 | 60.000 | -563.482 | 90.0 | 64.5 | ROTATE |
| F009-S | 10 | -590.910 | 60.000 | -562.268 | 51.0 | 150.0 | ROTATE |
| F010-H | 10 | -585.457 | 60.000 | -563.709 | 90.0 | 110.7 | ROTATE |
| F010-S | 10 | -584.298 | 60.000 | -563.884 | 0.0 | 67.2 | no |
| F011-H | 10 | -590.455 | 60.000 | -563.830 | 0.0 | 41.4 | no |
| F011-S | 10 | -586.821 | 60.000 | -564.212 | 0.0 | 46.8 | no |
| F012-H | 10 | -589.425 | 60.000 | -564.308 | 0.0 | 88.5 | no |
| F012-S | 10 | -585.433 | 60.000 | -563.759 | 0.0 | 69.6 | no |
| F013-H | 10 | -583.739 | 60.000 | -563.045 | 0.0 | 93.3 | no |
| F013-S | 10 | -591.149 | 60.000 | -563.253 | 0.0 | 145.2 | no |
| F014-H | 10 | -587.272 | 60.000 | -564.242 | 0.0 | 61.8 | no |
| F014-S | 10 | -586.002 | 60.000 | -563.586 | 0.0 | 67.5 | no |
| F015-H | 10 | -588.530 | 60.000 | -563.996 | 0.0 | 80.7 | no |
| F015-S | 10 | -582.929 | 60.000 | -563.171 | 0.0 | 109.8 | no |
| F016-H | 10 | -587.176 | 60.000 | -564.194 | 45.0 | 32.4 | ROTATE |
| F016-S | 10 | -588.382 | 60.000 | -564.331 | 0.0 | 36.0 | no |
| F017-H | 10 | -588.083 | 60.000 | -564.116 | 90.0 | 47.7 | ROTATE |
| F017-S | 10 | -585.748 | 60.000 | -563.732 | 0.0 | 72.6 | no |
| F018-H | 10 | -588.168 | 60.000 | -564.277 | 0.0 | 37.5 | no |
| F018-S | 10 | -586.196 | 60.000 | -564.135 | 0.0 | 37.8 | no |
| F019-H | 10 | -576.714 | 60.000 | -564.008 | 0.0 | 41.4 | no |
| F019-S | 10 | -588.247 | 60.000 | -563.074 | 0.0 | 97.2 | no |
| F020-H | 10 | -589.735 | 60.000 | -563.662 | 0.0 | 71.1 | no |

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|---|---|---|---|---|---|---|---|
| F020-S | 10 | -587.765 | 60.000 | -564.013 | 0.0 | 59.4 | no |
| F021-H | 10 | -586.064 | 60.000 | -563.343 | 0.0 | 85.5 | no |
| F021-S | 10 | -584.687 | 60.000 | -564.261 | 0.0 | 87.9 | no |
| F022-H | 10 | -582.343 | 60.000 | -563.162 | 90.0 | 80.7 | ROTATE |
| F022-S | 10 | -585.336 | 60.000 | -563.783 | 0.0 | 77.1 | no |
| F023-H | 10 | -587.890 | 60.000 | -564.379 | 0.0 | 43.8 | no |
| F023-S | 10 | -585.200 | 60.000 | -563.514 | 0.0 | 94.5 | no |
| F024-H | 10 | -583.173 | 60.000 | -563.876 | 90.0 | 54.6 | ROTATE |
| F024-S | 10 | -584.754 | 60.000 | -564.074 | 0.0 | 42.0 | no |
| F025-H | 10 | -583.131 | 60.000 | -564.074 | 0.0 | 56.4 | no |
| F025-S | 10 | -589.597 | 60.000 | -564.239 | 0.0 | 71.4 | no |
| F026-H | 10 | -588.387 | 60.000 | -563.622 | 90.0 | 95.1 | ROTATE |
| F026-S | 10 | -587.209 | 60.000 | -564.233 | 0.0 | 38.7 | no |
| F027-H | 10 | -588.399 | 60.000 | -564.438 | 0.0 | 67.8 | no |
| F027-S | 10 | -583.986 | 60.000 | -563.157 | 0.0 | 86.1 | no |
| F028-H | 10 | -590.163 | 60.000 | -563.338 | 90.0 | 129.6 | ROTATE |
| F028-S | 10 | -586.270 | 60.000 | -563.938 | 0.0 | 122.4 | no |
| F029-H | 10 | -592.510 | 60.000 | -563.356 | 0.0 | 73.5 | no |
| F029-S | 10 | -589.594 | 60.000 | -564.148 | 0.0 | 69.3 | no |
| F030-H | 10 | -585.609 | 60.000 | -563.130 | 90.0 | 90.0 | ROTATE |
| F030-S | 10 | -583.090 | 60.000 | -563.930 | 0.0 | 72.3 | no |
| F031-H | 10 | -589.016 | 60.000 | -564.215 | 0.0 | 37.8 | no |
| F031-S | 10 | -586.462 | 60.000 | -564.127 | 0.0 | 74.4 | no |
| F032-H | 10 | -587.919 | 60.000 | -563.903 | 90.0 | 93.6 | ROTATE |
| F032-S | 10 | -587.081 | 60.000 | -564.437 | 0.0 | 53.1 | no |
| F033-H | 10 | -590.390 | 60.000 | -563.525 | 0.0 | 148.5 | no |
| F033-S | 10 | -585.507 | 60.000 | -562.734 | 0.0 | 146.1 | no |
| F034-H | 10 | -593.287 | 60.000 | -563.124 | 0.0 | 104.4 | no |
| F034-S | 10 | -591.871 | 60.000 | -563.056 | 0.0 | 120.9 | no |
| F035-H | 10 | -586.094 | 60.000 | -564.373 | 90.0 | 63.0 | ROTATE |
| F035-S | 10 | -589.746 | 60.000 | -563.965 | 18.0 | 48.0 | ROTATE |
| F036-H | 10 | -589.347 | 60.000 | -563.956 | 0.0 | 53.4 | no |
| F036-S | 10 | -587.507 | 60.000 | -564.137 | 0.0 | 41.4 | no |
| F037-H | 10 | -589.854 | 60.000 | -564.454 | 0.0 | 81.0 | no |
| F037-S | 10 | -588.808 | 60.000 | -563.807 | 0.0 | 110.1 | no |
| F038-H | 10 | -579.858 | 60.000 | -564.141 | 57.0 | 57.9 | ROTATE |
| F038-S | 10 | -587.523 | 60.000 | -563.858 | 0.0 | 46.5 | no |
| F040-H | 10 | -587.985 | 60.000 | -563.967 | 0.0 | 51.6 | no |
| F040-S | 10 | -583.958 | 60.000 | -563.955 | 0.0 | 51.3 | no |
| F041-H | 10 | -581.405 | 60.000 | -564.421 | 0.0 | 32.1 | no |
| F041-S | 10 | -583.327 | 60.000 | -564.142 | 0.0 | 46.5 | no |
| F042-H | 10 | -592.487 | 60.000 | -563.617 | 0.0 | 57.6 | no |
| F042-S | 10 | -589.150 | 60.000 | -564.393 | 0.0 | 60.6 | no |
| F043-H | 10 | -587.355 | 60.000 | -563.958 | 0.0 | 34.8 | no |
| F043-S | 10 | -588.536 | 60.000 | -564.074 | 0.0 | 42.9 | no |
| H001-H | 10 | -588.081 | 60.000 | -564.479 | 0.0 | 39.6 | no |
| H002-H | 10 | -590.653 | 60.000 | -564.173 | 0.0 | 48.6 | no |
| H003-H | 10 | -592.202 | 60.000 | -563.918 | 0.0 | 71.7 | no |
| I001-H | 10 | -581.935 | 60.000 | -563.146 | 0.0 | 84.0 | no |
| I001-S | 10 | -587.476 | 60.000 | -564.069 | 0.0 | 70.5 | no |
| P001-H | 10 | -589.005 | 60.000 | -564.250 | 90.0 | 51.3 | ROTATE |
| P001-S | 10 | -587.981 | 60.000 | -564.434 | 0.0 | 51.3 | no |
| P002-H | 10 | -588.443 | 60.000 | -564.355 | 0.0 | 80.7 | no |
| P002-S | 10 | -586.633 | 60.000 | -564.087 | 0.0 | 57.9 | no |
| P003-H | 10 | -591.523 | 60.000 | -564.329 | 0.0 | 29.4 | no |
| P003-S | 10 | -588.449 | 60.000 | -564.341 | 0.0 | 30.9 | no |
| P004-H | 10 | -589.400 | 60.000 | -563.774 | 0.0 | 78.3 | no |
| P004-S | 10 | -588.782 | 60.000 | -564.196 | 0.0 | 42.3 | no |
| P005-H | 10 | -589.962 | 60.000 | -564.201 | 90.0 | 51.9 | ROTATE |
| P005-S | 10 | -585.360 | 60.000 | -564.351 | 90.0 | 62.4 | ROTATE |

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|---|---|---|---|---|---|---|---|
| P006-H | 10 | -580.536 | 60.000 | -564.351 | 0.0 | 40.2 | no |
| P006-S | 10 | -590.254 | 60.000 | -564.343 | 0.0 | 59.7 | no |
| P007-H | 10 | -588.628 | 60.000 | -564.150 | 0.0 | 26.1 | no |
| P007-S | 10 | -587.662 | 60.000 | -563.845 | 0.0 | 54.3 | no |
| P008-H | 10 | -583.009 | 60.000 | -563.882 | 0.0 | 134.1 | no |
| P008-S | 10 | -586.262 | 60.000 | -564.299 | 0.0 | 61.8 | no |
| P009-H | 10 | -588.635 | 60.000 | -563.565 | 0.0 | 84.9 | no |
| P009-S | 10 | -581.004 | 60.000 | -562.952 | 0.0 | 143.1 | no |
| P010-H | 10 | -581.476 | 60.000 | -564.426 | 0.0 | 72.9 | no |
| P010-S | 10 | -586.972 | 60.000 | -563.470 | 0.0 | 61.5 | no |

## Task Room 11 Reduced Data

| File | Room | X | Y | Z | Rotate | Speed | RESULT |
|---|---|---|---|---|---|---|---|
| A001-H | 11 | -123.941 | 60.000 | -735.466 | 0.0 | 54.3 | CATCH |
| A002-H | 11 | -123.399 | 60.000 | -735.048 | 0.0 | 55.5 | CATCH |
| A003-H | 11 | -123.666 | 60.000 | -727.359 | 90.0 | 43.5 | CATCH |
| A004-H | 11 | -124.046 | 60.000 | -729.577 | 0.0 | 80.7 | CATCH |
| A005-H | 11 | -124.016 | 60.000 | -726.603 | 0.0 | 48.3 | CATCH |
| B001-H | 11 | -123.282 | 60.000 | -738.370 | 0.0 | 17.4 | CATCH |
| B001-S | 11 | -123.345 | 60.000 | -726.102 | 0.0 | 21.3 | CATCH |
| B002-H | 11 | -124.106 | 60.000 | -735.768 | 0.0 | 57.9 | CATCH |
| B002-S | 11 | -124.911 | 60.000 | -729.685 | 0.0 | 117.9 | CATCH |
| B003-H | 11 | -123.717 | 60.000 | -733.469 | 0.0 | 40.8 | CATCH |
| B003-S | 11 | -123.829 | 60.000 | -734.107 | 0.0 | 66.0 | CATCH |
| B004-H | 11 | -123.441 | 60.000 | -739.588 | 0.0 | 43.8 | CATCH |
| B004-S | 11 | -123.660 | 60.000 | -731.890 | 0.0 | 93.6 | CATCH |
| B005-H | 11 | -123.298 | 60.000 | -742.101 | 0.0 | 35.1 | CATCH |
| B005-S | 11 | -123.670 | 60.000 | -631.578 | 0.0 | 38.4 | not |
| F001-H | 11 | -123.653 | 60.000 | -735.470 | 0.0 | 29.4 | CATCH |
| F001-S | 11 | -123.327 | 60.000 | -734.622 | 0.0 | 61.5 | CATCH |
| F002-H | 11 | -124.753 | 60.000 | -734.947 | 0.0 | 112.2 | CATCH |
| F002-S | 11 | -123.335 | 60.000 | -727.334 | 0.0 | 65.1 | CATCH |
| F003-H | 11 | -123.681 | 60.000 | -728.470 | 0.0 | 65.4 | CATCH |
| F003-S | 11 | -124.538 | 60.000 | -723.084 | 0.0 | 111.3 | CATCH |
| F004-H | 11 | -124.120 | 60.000 | -729.021 | 0.0 | 64.8 | CATCH |
| F004-S | 11 | -123.983 | 60.000 | -731.174 | 0.0 | 81.0 | CATCH |
| F005-H | 11 | -124.322 | 60.000 | -727.926 | 0.0 | 87.3 | CATCH |
| F005-S | 11 | -123.510 | 60.000 | -727.972 | 0.0 | 110.1 | CATCH |
| F006-H | 11 | -124.090 | 60.000 | -735.204 | 0.0 | 93.3 | CATCH |
| F006-S | 11 | -124.804 | 60.000 | -741.313 | 0.0 | 102.9 | CATCH |
| F007-H | 11 | -123.286 | 60.000 | -724.796 | 90.0 | 46.2 | CATCH |
| F007-S | 11 | -123.631 | 60.000 | -726.128 | 0.0 | 65.1 | CATCH |
| F008-H | 11 | -123.604 | 60.000 | -733.889 | 0.0 | 29.1 | CATCH |
| F008-S | 11 | -123.486 | 60.000 | -728.102 | 0.0 | 51.6 | CATCH |
| F009-H | 11 | -123.335 | 60.000 | -730.159 | 90.0 | 65.1 | CATCH |
| F009-S | 11 | -124.943 | 60.000 | -704.807 | 24.0 | 127.2 | CATCH |
| F010-H | 11 | -123.537 | 60.000 | -736.337 | 0.0 | 85.5 | CATCH |
| F010-S | 11 | -123.684 | 60.000 | -730.063 | 0.0 | 66.3 | CATCH |
| F011-H | 11 | -123.310 | 60.000 | -732.574 | 0.0 | 25.2 | CATCH |
| F011-S | 11 | -123.523 | 60.000 | -615.007 | 0.0 | 42.6 | not |
| F012-H | 11 | -123.553 | 60.000 | -730.601 | 0.0 | 75.9 | CATCH |
| F012-S | 11 | -123.609 | 60.000 | -723.694 | 0.0 | 78.0 | CATCH |
| F013-H | 11 | -124.882 | 60.000 | -735.362 | 0.0 | 102.6 | CATCH |
| F013-S | 11 | -125.391 | 60.000 | -723.392 | 0.0 | 146.1 | CATCH |
| F014-H | 11 | -124.071 | 60.000 | -728.959 | 0.0 | 62.4 | CATCH |
| F014-S | 11 | -123.707 | 60.000 | -730.003 | 0.0 | 55.5 | CATCH |
| F015-H | 11 | -123.668 | 60.000 | -730.975 | 0.0 | 77.1 | CATCH |
| F015-S | 11 | -123.778 | 60.000 | -729.512 | 0.0 | 112.2 | CATCH |
| F016-H | 11 | -123.495 | 60.000 | -730.950 | 90.0 | 36.3 | CATCH |

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|---|---|---|---|---|---|---|---|
| F016-S | 11 | -123.484 | 60.000 | -634.476 | 90.0 | 26.4 | not |
| F017-H | 11 | -123.986 | 60.000 | -734.902 | 0.0 | 48.3 | CATCH |
| F017-S | 11 | -123.442 | 60.000 | -726.903 | 0.0 | 47.7 | CATCH |
| F018-H | 11 | -123.970 | 60.000 | -728.243 | 0.0 | 51.0 | CATCH |
| F018-S | 11 | -124.018 | 60.000 | -727.154 | 0.0 | 55.5 | CATCH |
| F019-H | 11 | -123.914 | 60.000 | -732.767 | 0.0 | 63.6 | CATCH |
| F019-S | 11 | -124.918 | 60.000 | -730.441 | 0.0 | 117.9 | CATCH |
| F020-H | 11 | -124.130 | 60.000 | -730.587 | 0.0 | 70.5 | CATCH |
| F020-S | 11 | -123.354 | 60.000 | -726.948 | 0.0 | 68.4 | CATCH |
| F021-H | 11 | -123.381 | 60.000 | -729.940 | 0.0 | 86.4 | CATCH |
| F021-S | 11 | -124.967 | 60.000 | -731.067 | 0.0 | 118.5 | CATCH |
| F022-H | 11 | -124.402 | 60.000 | -733.671 | 0.0 | 74.4 | CATCH |
| F022-S | 11 | -124.362 | 60.000 | -730.659 | 0.0 | 78.0 | CATCH |
| F023-H | 11 | -123.901 | 60.000 | -735.129 | 0.0 | 47.7 | CATCH |
| F023-S | 11 | -124.214 | 60.000 | -738.848 | 0.0 | 97.8 | CATCH |
| F024-H | 11 | -123.583 | 60.000 | -736.801 | 0.0 | 48.3 | CATCH |
| F024-S | 11 | -123.637 | 60.000 | -730.027 | 0.0 | 25.2 | CATCH |
| F025-H | 11 | -123.647 | 60.000 | -732.129 | 0.0 | 40.2 | CATCH |
| F025-S | 11 | -123.351 | 60.000 | -731.548 | 0.0 | 81.3 | CATCH |
| F026-H | 11 | -123.812 | 60.000 | -735.964 | 0.0 | 99.6 | CATCH |
| F026-S | 11 | -124.380 | 60.000 | -732.117 | 0.0 | 75.3 | CATCH |
| F027-H | 11 | -123.898 | 60.000 | -727.982 | 0.0 | 58.2 | CATCH |
| F027-S | 11 | -123.503 | 60.000 | -729.089 | 0.0 | 79.5 | CATCH |
| F028-H | 11 | -125.317 | 60.000 | -747.580 | 0.0 | 138.9 | CATCH |
| F028-S | 11 | -124.208 | 60.000 | -724.997 | 0.0 | 148.2 | CATCH |
| F029-H | 11 | -123.265 | 60.000 | -735.714 | 0.0 | 69.6 | CATCH |
| F029-S | 11 | -123.587 | 60.000 | -732.289 | 0.0 | 37.5 | CATCH |
| F030-H | 11 | -124.337 | 60.000 | -729.809 | 0.0 | 85.8 | CATCH |
| F030-S | 11 | -123.511 | 60.000 | -726.450 | 0.0 | 87.3 | CATCH |
| F031-H | 11 | -123.606 | 60.000 | -624.242 | 0.0 | 26.7 | not |
| F031-S | 11 | -123.505 | 60.000 | -729.913 | 0.0 | 56.1 | CATCH |
| F032-H | 11 | -123.819 | 60.000 | -728.939 | 0.0 | 51.6 | CATCH |
| F032-S | 11 | -123.930 | 60.000 | -733.462 | 0.0 | 71.1 | CATCH |
| F033-H | 11 | -123.943 | 60.000 | -737.077 | 0.0 | 121.8 | CATCH |
| F033-S | 11 | -125.243 | 60.000 | -729.156 | 0.0 | 145.2 | CATCH |
| F034-H | 11 | -124.586 | 60.000 | -734.782 | 0.0 | 102.6 | CATCH |
| F034-S | 11 | -123.893 | 60.000 | -727.415 | 0.0 | 124.8 | CATCH |
| F035-H | 11 | -123.951 | 60.000 | -728.802 | 90.0 | 48.6 | CATCH |
| F035-S | 11 | -123.774 | 60.000 | -725.799 | 90.0 | 46.5 | CATCH |
| F036-H | 11 | -123.736 | 60.000 | -736.853 | 0.0 | 42.9 | CATCH |
| F036-S | 11 | -123.722 | 60.000 | -731.711 | 0.0 | 33.0 | CATCH |
| F037-H | 11 | -124.118 | 60.000 | -731.017 | 0.0 | 62.1 | CATCH |
| F037-S | 11 | -124.816 | 60.000 | -731.463 | 0.0 | 133.2 | CATCH |
| F038-H | 11 | -123.387 | 60.000 | -737.809 | 0.0 | 56.7 | CATCH |
| F038-S | 11 | -123.989 | 60.000 | -736.234 | 0.0 | 50.1 | CATCH |
| F040-H | 11 | -123.861 | 60.000 | -733.916 | 0.0 | 53.1 | CATCH |
| F040-S | 11 | -123.485 | 60.000 | -731.325 | 0.0 | 42.6 | CATCH |
| F041-H | 11 | -123.296 | 60.000 | -733.825 | 0.0 | 12.9 | CATCH |
| F041-S | 11 | -123.706 | 60.000 | -731.511 | 0.0 | 33.0 | CATCH |
| F042-H | 11 | -123.839 | 60.000 | -740.398 | 0.0 | 54.0 | CATCH |
| F042-S | 11 | -123.351 | 60.000 | -734.413 | 0.0 | 60.6 | CATCH |
| F043-H | 11 | -123.547 | 60.000 | -728.883 | 0.0 | 42.9 | CATCH |
| F043-S | 11 | -123.274 | 60.000 | -729.556 | 0.0 | 56.1 | CATCH |
| H001-H | 11 | -124.011 | 60.000 | -736.214 | 0.0 | 53.1 | CATCH |
| H002-H | 11 | -123.504 | 60.000 | -739.725 | 0.0 | 32.1 | CATCH |
| H003-H | 11 | -123.727 | 60.000 | -729.268 | 0.0 | 67.2 | CATCH |
| I001-H | 11 | -123.459 | 60.000 | -731.159 | 0.0 | 79.8 | CATCH |
| I001-S | 11 | -123.641 | 60.000 | -734.269 | 0.0 | 46.8 | CATCH |
| P001-H | 11 | -124.191 | 60.000 | -623.002 | 0.0 | 60.9 | not |
| P001-S | 11 | -123.538 | 60.000 | -620.426 | 0.0 | 54.0 | not |

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|---|---|---|---|---|---|---|---|
| P002-H | 11 | -124.232 | 60.000 | -729.292 | 0.0 | 72.3 | CATCH |
| P002-S | 11 | -123.288 | 60.000 | -732.465 | 0.0 | 78.3 | CATCH |
| P003-H | 11 | -123.263 | 60.000 | -738.636 | 0.0 | 16.8 | CATCH |
| P003-S | 11 | -123.322 | 60.000 | -616.481 | 0.0 | 23.4 | not |
| P004-H | 11 | -124.042 | 60.000 | -749.716 | 0.0 | 51.3 | CATCH |
| P004-S | 11 | -124.094 | 60.000 | -731.709 | 0.0 | 55.8 | CATCH |
| P005-H | 11 | -123.928 | 60.000 | -732.765 | 90.0 | 42.9 | CATCH |
| P005-S | 11 | -123.719 | 60.000 | -730.981 | 90.0 | 46.2 | CATCH |
| P006-H | 11 | -123.256 | 60.000 | -746.357 | 0.0 | 13.2 | CATCH |
| P006-S | 11 | -123.765 | 60.000 | -616.916 | 0.0 | 63.0 | not |
| P007-H | 11 | -123.344 | 60.000 | -733.026 | 0.0 | 24.6 | CATCH |
| P007-S | 11 | -123.624 | 60.000 | -729.615 | 0.0 | 27.0 | CATCH |
| P008-H | 11 | -123.384 | 60.000 | -737.737 | 0.0 | 80.7 | CATCH |
| P008-S | 11 | -123.607 | 60.000 | -737.902 | 0.0 | 100.5 | CATCH |
| P009-H | 11 | -124.393 | 60.000 | -727.585 | 0.0 | 80.1 | CATCH |
| P009-S | 11 | -125.095 | 60.000 | -726.831 | 0.0 | 129.9 | CATCH |
| P010-H | 11 | -123.350 | 60.000 | -724.152 | 0.0 | 73.5 | CATCH |
| P010-S | 11 | -123.495 | 60.000 | -727.072 | 0.0 | 54.3 | CATCH |

## Task Room 12 Reduced Data

| File | Room | X | Y | Z | Rotate | Speed | RESULT |
|---|---|---|---|---|---|---|---|
| A001-H | 12 | -63.447 | 60.000 | -221.862 | 0.0 | 61.2 | no |
| A002-H | 12 | -41.235 | 60.000 | -222.250 | 0.0 | 77.7 | no |
| A003-H | 12 | 25.280 | 125.000 | -221.899 | 0.0 | 75.6 | FLY |
| A004-H | 12 | -49.962 | 60.000 | -221.680 | 0.0 | 83.7 | no |
| A005-H | 12 | -49.070 | 60.000 | -222.086 | 0.0 | 60.6 | no |
| B001-H | 12 | -51.791 | 60.000 | -221.683 | 0.0 | 21.6 | no |
| B001-S | 12 | -52.388 | 60.000 | -221.665 | 0.0 | 25.8 | no |
| B002-H | 12 | 53.075 | 125.000 | -221.992 | 30.0 | 49.2 | FLY |
| B002-S | 12 | -63.472 | 60.000 | -222.128 | 0.0 | 110.1 | no |
| B003-H | 12 | 42.143 | 125.000 | -221.807 | 0.0 | 48.6 | FLY |
| B003-S | 12 | -49.172 | 60.000 | -221.529 | 0.0 | 70.2 | no |
| B004-H | 12 | 53.190 | 125.000 | -221.941 | 0.0 | 47.4 | FLY |
| B004-S | 12 | -44.493 | 60.000 | -223.100 | 0.0 | 98.7 | no |
| B005-H | 12 | -33.621 | 60.000 | -221.857 | 0.0 | 32.7 | no |
| B005-S | 12 | -43.363 | 60.000 | -221.699 | 0.0 | 49.2 | no |
| F001-H | 12 | 41.856 | 125.000 | -221.732 | 0.0 | 53.1 | FLY |
| F001-S | 12 | 51.088 | 125.000 | -222.062 | 0.0 | 90.6 | FLY |
| F002-H | 12 | 46.178 | 87.000 | -222.830 | 0.0 | 107.4 | FLY |
| F002-S | 12 | 43.910 | 125.000 | -222.643 | 0.0 | 71.4 | FLY |
| F003-H | 12 | 48.289 | 125.000 | -221.579 | 0.0 | 88.8 | FLY |
| F003-S | 12 | 32.735 | 125.000 | -222.527 | 0.0 | 116.7 | FLY |
| F004-H | 12 | -47.895 | 60.000 | -222.353 | 0.0 | 86.7 | no |
| F004-S | 12 | -53.251 | 60.000 | -222.392 | 0.0 | 101.1 | no |
| F005-H | 12 | 43.336 | 125.000 | -221.963 | 0.0 | 147.6 | FLY |
| F005-S | 12 | 45.192 | 125.000 | -223.018 | 0.0 | 132.0 | FLY |
| F006-H | 12 | -43.412 | 60.000 | -222.330 | 0.0 | 82.2 | no |
| F006-S | 12 | -51.649 | 60.000 | -221.639 | 0.0 | 58.8 | no |
| F007-H | 12 | 40.613 | 125.000 | -222.305 | 0.0 | 52.5 | FLY |
| F007-S | 12 | -54.894 | 60.000 | -221.599 | 0.0 | 54.0 | no |
| F008-H | 12 | 39.100 | 125.000 | -221.959 | 0.0 | 56.4 | FLY |
| F008-S | 12 | -58.639 | 60.000 | -221.821 | 0.0 | 40.2 | no |
| F009-H | 12 | 51.159 | 125.000 | -221.713 | 0.0 | 94.5 | FLY |
| F009-S | 12 | 42.648 | 108.000 | -221.574 | 0.0 | 150.0 | FLY |
| F010-H | 12 | 40.875 | 125.000 | -222.161 | 0.0 | 79.2 | FLY |
| F010-S | 12 | 40.104 | 125.000 | -221.963 | 0.0 | 65.7 | FLY |
| F011-H | 12 | -52.229 | 60.000 | -221.873 | 0.0 | 33.3 | no |
| F011-S | 12 | -54.754 | 60.000 | -222.221 | 0.0 | 56.4 | no |
| F012-H | 12 | -46.399 | 60.000 | -222.478 | 0.0 | 81.3 | no |

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|---|---|---|---|---|---|---|---|
| F012-S | 12 | -59.236 | 60.000 | -221.576 | 0.0 | 79.5 | no |
| F013-H | 12 | -38.470 | 60.000 | -222.490 | 0.0 | 93.0 | no |
| F013-S | 12 | -47.744 | 60.000 | -222.772 | 0.0 | 150.0 | no |
| F014-H | 12 | 37.325 | 125.000 | -222.056 | 0.0 | 52.8 | FLY |
| F014-S | 12 | -41.922 | 60.000 | -222.057 | 0.0 | 51.9 | no |
| F015-H | 12 | -52.331 | 60.000 | -221.502 | 0.0 | 64.5 | no |
| F015-S | 12 | -56.206 | 60.000 | -223.267 | 0.0 | 123.6 | no |
| F016-H | 12 | -52.962 | 60.000 | -221.601 | 90.0 | 17.4 | m/b |
| F016-S | 12 | 30.931 | 125.000 | -221.547 | 0.0 | 25.5 | FLY |
| F017-H | 12 | 48.734 | 125.000 | -221.633 | 0.0 | 45.6 | FLY |
| F017-S | 12 | -50.670 | 60.000 | -222.073 | 0.0 | 57.9 | no |
| F018-H | 12 | 43.163 | 125.000 | -221.716 | 0.0 | 61.2 | FLY |
| F018-S | 12 | -50.831 | 60.000 | -221.546 | 0.0 | 49.5 | no |
| F019-H | 12 | 58.063 | 125.000 | -221.883 | 0.0 | 72.9 | FLY |
| F019-S | 12 | 66.420 | 125.000 | -222.637 | 0.0 | 120.3 | FLY |
| F020-H | 12 | 32.939 | 125.000 | -221.802 | 0.0 | 71.1 | FLY |
| F020-S | 12 | -61.512 | 60.000 | -221.682 | 0.0 | 79.5 | no |
| F021-H | 12 | 45.503 | 125.000 | -221.529 | 0.0 | 117.3 | FLY |
| F021-S | 12 | -61.055 | 60.000 | -223.419 | 0.0 | 121.5 | no |
| F022-H | 12 | -45.396 | 60.000 | -222.534 | 0.0 | 75.6 | no |
| F022-S | 12 | -50.046 | 60.000 | -222.743 | 0.0 | 80.7 | no |
| F023-H | 12 | 46.271 | 125.000 | -221.980 | 0.0 | 43.5 | FLY |
| F023-S | 12 | -42.425 | 60.000 | -221.528 | 0.0 | 82.5 | no |
| F024-H | 12 | -45.898 | 60.000 | -221.766 | 90.0 | 49.2 | m/b |
| F024-S | 12 | -55.263 | 60.000 | -221.674 | 0.0 | 50.4 | no |
| F025-H | 12 | 48.883 | 125.000 | -221.604 | 0.0 | 48.3 | FLY |
| F025-S | 12 | -50.433 | 60.000 | -222.226 | 0.0 | 71.7 | no |
| F026-H | 12 | -56.813 | 60.000 | -222.805 | 0.0 | 101.1 | no |
| F026-S | 12 | -60.714 | 60.000 | -221.613 | 0.0 | 69.0 | no |
| F027-H | 12 | 46.701 | 125.000 | -222.350 | 0.0 | 56.4 | FLY |
| F027-S | 12 | -30.665 | 60.000 | -222.141 | 0.0 | 87.0 | no |
| F028-H | 12 | -35.924 | 60.000 | -222.540 | 90.0 | 69.6 | m/b |
| F028-S | 12 | -46.481 | 60.000 | -222.268 | 0.0 | 131.7 | no |
| F029-H | 12 | 43.596 | 125.000 | -221.901 | 0.0 | 60.9 | FLY |
| F029-S | 12 | -58.731 | 60.000 | -221.903 | 0.0 | 25.5 | no |
| F030-H | 12 | -29.026 | 60.000 | -221.782 | 0.0 | 22.5 | no |
| F030-S | 12 | -55.933 | 60.000 | -222.423 | 0.0 | 76.5 | no |
| F031-H | 12 | -53.720 | 60.000 | -221.976 | 0.0 | 35.7 | no |
| F031-S | 12 | -52.614 | 60.000 | -222.049 | 0.0 | 69.3 | no |
| F032-H | 12 | 47.722 | 125.000 | -221.897 | 0.0 | 72.9 | FLY |
| F032-S | 12 | -47.934 | 60.000 | -222.257 | 0.0 | 63.6 | no |
| F033-H | 12 | -54.968 | 60.000 | -221.766 | 0.0 | 130.2 | no |
| F033-S | 12 | 42.057 | 102.000 | -221.983 | 0.0 | 150.0 | FLY |
| F034-H | 12 | -49.449 | 60.000 | -222.535 | 0.0 | 109.2 | no |
| F034-S | 12 | -55.113 | 60.000 | -223.262 | 0.0 | 123.3 | no |
| F035-H | 12 | -47.254 | 60.000 | -221.948 | 90.0 | 31.2 | m/b |
| F035-S | 12 | -54.976 | 60.000 | -222.130 | 90.0 | 44.4 | m/b |
| F036-H | 12 | 47.485 | 125.000 | -221.651 | 0.0 | 37.2 | FLY |
| F036-S | 12 | -50.428 | 60.000 | -221.720 | 0.0 | 21.3 | no |
| F037-H | 12 | 40.850 | 125.000 | -221.769 | 0.0 | 73.2 | FLY |
| F037-S | 12 | -57.767 | 60.000 | -221.968 | 0.0 | 112.2 | no |
| F038-H | 12 | 52.111 | 90.000 | -222.763 | 0.0 | 103.5 | FLY |
| F038-S | 12 | -35.296 | 60.000 | -221.993 | 0.0 | 45.3 | no |
| F040-H | 12 | 42.491 | 125.000 | -221.956 | 0.0 | 58.8 | FLY |
| F040-S | 12 | -61.386 | 60.000 | -221.956 | 0.0 | 51.3 | no |
| F041-H | 12 | 69.412 | 60.000 | -221.516 | 0.0 | 68.7 | no |
| F041-S | 12 | -47.743 | 60.000 | -221.713 | 0.0 | 20.7 | no |
| F042-H | 12 | -45.345 | 60.000 | -221.925 | 90.0 | 44.1 | m/b |
| F042-S | 12 | -53.994 | 60.000 | -221.713 | 0.0 | 66.0 | no |
| F043-H | 12 | 31.125 | 125.000 | -222.158 | 0.0 | 52.5 | FLY |

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|---|---|---|---|---|---|---|---|
| F043-S | 12 | -53.686 | 60.000 | -221.917 | 0.0 | 50.7 | no |
| H001-H | 12 | -54.536 | 60.000 | -222.525 | 0.0 | 77.7 | no |
| H002-H | 12 | 40.814 | 87.000 | -221.516 | 0.0 | 33.9 | FLY |
| H003-H | 12 | -49.562 | 60.000 | -222.206 | 0.0 | 62.1 | no |
| I001-H | 12 | 47.589 | 125.000 | -221.838 | 0.0 | 41.7 | FLY |
| I001-S | 12 | -53.998 | 60.000 | -221.839 | 0.0 | 60.0 | no |
| P001-H | 12 | -35.431 | 60.000 | -222.889 | 0.0 | 93.0 | no |
| P001-S | 12 | -42.938 | 60.000 | -222.269 | 0.0 | 70.2 | no |
| P002-H | 12 | -45.997 | 60.000 | -222.258 | 0.0 | 62.1 | no |
| P002-S | 12 | -52.619 | 60.000 | -221.572 | 0.0 | 90.3 | no |
| P003-H | 12 | -25.452 | 60.000 | -221.501 | 0.0 | 11.1 | no |
| P003-S | 12 | -46.289 | 60.000 | -221.670 | 0.0 | 28.8 | no |
| P004-H | 12 | 54.430 | 158.000 | -221.918 | 0.0 | 58.8 | FLY |
| P004-S | 12 | -49.644 | 60.000 | -221.945 | 0.0 | 35.1 | no |
| P005-H | 12 | -47.525 | 60.000 | -221.801 | 9.0 | 45.9 | m/b |
| P005-S | 12 | 45.327 | 138.000 | -221.890 | 0.0 | 74.1 | FLY |
| P006-H | 12 | -51.820 | 60.000 | -221.511 | 0.0 | 64.8 | no |
| P006-S | 12 | 24.458 | 148.000 | -221.601 | 0.0 | 40.5 | FLY |
| P007-H | 12 | -45.839 | 60.000 | -222.196 | 0.0 | 42.6 | no |
| P007-S | 12 | 43.900 | 250.000 | -221.884 | 0.0 | 32.1 | FLY |
| P008-H | 12 | -48.879 | 60.000 | -222.073 | 0.0 | 72.3 | no |
| P008-S | 12 | -47.607 | 60.000 | -222.290 | 0.0 | 58.5 | no |
| P009-H | 12 | -53.033 | 60.000 | -222.668 | 0.0 | 87.3 | no |
| P009-S | 12 | -48.000 | 60.000 | -222.449 | 0.0 | 149.7 | no |
| P010-H | 12 | -36.143 | 60.000 | -221.542 | 0.0 | 74.1 | no |
| P010-S | 12 | -40.722 | 60.000 | -222.217 | 0.0 | 51.0 | no |

## Task Room 13 Reduced Data

| File | Room | X | Y | Z | Rotate | Speed | RESULT |
|---|---|---|---|---|---|---|---|
| A001-H | 13 | 465.552 | 60.000 | -97.818 | 90.0 | 54.0 | ROTATE |
| A002-H | 13 | 466.159 | 60.000 | -98.605 | 90.0 | 93.0 | ROTATE |
| A003-H | 13 | 465.986 | 60.000 | 19.700 | 0.0 | 93.9 | no |
| A004-H | 13 | 466.044 | 60.000 | -98.015 | 0.0 | 84.3 | no |
| A005-H | 13 | 465.160 | 60.000 | -99.774 | 90.0 | 80.4 | ROTATE |
| B001-H | 13 | 466.175 | 60.000 | -109.019 | 0.0 | 10.8 | no |
| B001-S | 13 | 466.048 | 60.000 | -85.018 | 0.0 | 30.6 | no |
| B002-H | 13 | 465.706 | 60.000 | -108.746 | 54.0 | 55.5 | ROTATE |
| B002-S | 13 | 466.214 | 60.000 | -77.950 | 0.0 | 63.0 | no |
| B003-H | 13 | 466.097 | 60.000 | -104.858 | 0.0 | 48.9 | no |
| B003-S | 13 | 465.818 | 60.000 | -80.472 | 0.0 | 70.2 | no |
| B004-H | 13 | 465.558 | 60.000 | -103.805 | 0.0 | 44.1 | no |
| B004-S | 13 | 466.111 | 60.000 | -83.293 | 0.0 | 97.8 | no |
| B005-H | 13 | 465.983 | 60.000 | -111.002 | 0.0 | 26.1 | no |
| B005-S | 13 | 466.055 | 60.000 | -86.041 | 0.0 | 53.4 | no |
| F001-H | 13 | 465.821 | 60.000 | -83.129 | 0.0 | 27.6 | no |
| F001-S | 13 | 465.915 | 60.000 | -84.825 | 0.0 | 32.1 | no |
| F002-H | 13 | 464.331 | 60.000 | -74.948 | 0.0 | 118.8 | no |
| F002-S | 13 | 465.422 | 60.000 | -87.323 | 90.0 | 72.6 | ROTATE |
| F003-H | 13 | 465.347 | 60.000 | -89.867 | 0.0 | 76.5 | no |
| F003-S | 13 | 464.365 | 60.000 | -82.767 | 90.0 | 111.3 | ROTATE |
| F004-H | 13 | 465.231 | 60.000 | -78.041 | 0.0 | 92.1 | no |
| F004-S | 13 | 465.201 | 60.000 | -86.083 | 0.0 | 69.9 | no |
| F005-H | 13 | 465.347 | 60.000 | -83.588 | 90.0 | 63.6 | ROTATE |
| F005-S | 13 | 465.815 | 60.000 | -81.094 | 0.0 | 127.2 | no |
| F006-H | 13 | 466.234 | 60.000 | -84.964 | 0.0 | 93.9 | no |
| F006-S | 13 | 465.974 | 60.000 | -83.382 | 0.0 | 64.8 | no |
| F007-H | 13 | 465.788 | 60.000 | -83.862 | 90.0 | 51.9 | ROTATE |
| F007-S | 13 | 466.012 | 60.000 | -84.436 | 90.0 | 69.0 | ROTATE |
| F008-H | 13 | 465.767 | 60.000 | -83.432 | 0.0 | 29.4 | no |

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|---|---|---|---|---|---|---|---|
| F008-S | 13 | 465.988 | 60.000 | -83.763 | 0.0 | 36.0 | no |
| F009-H | 13 | 465.594 | 60.000 | -95.796 | 90.0 | 75.0 | ROTATE |
| F009-S | 13 | 466.039 | 60.000 | -85.152 | 42.0 | 150.0 | ROTATE |
| F010-H | 13 | 465.623 | 60.000 | -88.587 | 90.0 | 82.5 | ROTATE |
| F010-S | 13 | 466.009 | 60.000 | -83.444 | 0.0 | 82.5 | no |
| F011-H | 13 | 465.881 | 60.000 | -83.783 | 0.0 | 27.0 | no |
| F011-S | 13 | 465.470 | 60.000 | -81.786 | 0.0 | 58.2 | no |
| F012-H | 13 | 464.897 | 60.000 | -84.919 | 0.0 | 109.8 | no |
| F012-S | 13 | 464.701 | 60.000 | -84.243 | 0.0 | 103.5 | no |
| F013-H | 13 | 464.838 | 60.000 | -69.909 | 0.0 | 94.5 | no |
| F013-S | 13 | 465.392 | 60.000 | -69.010 | 0.0 | 150.0 | no |
| F014-H | 13 | 465.970 | 60.000 | -89.576 | 0.0 | 70.2 | no |
| F014-S | 13 | 464.513 | 60.000 | -91.468 | 0.0 | 113.4 | no |
| F015-H | 13 | 466.118 | 60.000 | -84.092 | 0.0 | 73.2 | no |
| F015-S | 13 | 465.522 | 60.000 | -80.509 | 0.0 | 125.7 | no |
| F016-H | 13 | 466.063 | 60.000 | -81.797 | 90.0 | 22.8 | ROTATE |
| F016-S | 13 | 466.080 | 60.000 | -85.229 | 90.0 | 22.2 | ROTATE |
| F017-H | 13 | 465.460 | 60.000 | -85.114 | 90.0 | 48.0 | ROTATE |
| F017-S | 13 | 465.811 | 60.000 | -85.209 | 0.0 | 44.1 | no |
| F018-H | 13 | 465.719 | 60.000 | -87.485 | 90.0 | 44.1 | ROTATE |
| F018-S | 13 | 466.152 | 60.000 | -81.749 | 0.0 | 57.0 | no |
| F019-H | 13 | 466.207 | 60.000 | -86.871 | 90.0 | 41.7 | ROTATE |
| F019-S | 13 | 465.763 | 60.000 | -80.588 | 0.0 | 67.8 | no |
| F020-H | 13 | 465.124 | 60.000 | -87.962 | 90.0 | 73.2 | ROTATE |
| F020-S | 13 | 465.656 | 60.000 | -81.869 | 0.0 | 78.6 | no |
| F021-H | 13 | 465.193 | 60.000 | -82.056 | 0.0 | 110.7 | no |
| F021-S | 13 | 465.975 | 60.000 | -87.056 | 0.0 | 108.0 | no |
| F022-H | 13 | 465.088 | 60.000 | -87.171 | 0.0 | 73.5 | no |
| F022-S | 13 | 465.466 | 60.000 | -86.270 | 0.0 | 59.4 | no |
| F023-H | 13 | 465.852 | 60.000 | -85.296 | 0.0 | 42.9 | no |
| F023-S | 13 | 465.464 | 60.000 | -84.169 | 0.0 | 94.5 | no |
| F024-H | 13 | 465.690 | 60.000 | -84.330 | 90.0 | 44.7 | ROTATE |
| F024-S | 13 | 466.110 | 60.000 | -82.280 | 0.0 | 46.8 | no |
| F025-H | 13 | 466.048 | 60.000 | -97.203 | 0.0 | 66.0 | no |
| F025-S | 13 | 465.345 | 60.000 | -83.655 | 0.0 | 80.1 | no |
| F026-H | 13 | 466.185 | 60.000 | -81.335 | 0.0 | 102.6 | no |
| F026-S | 13 | 465.188 | 60.000 | -82.812 | 0.0 | 75.0 | no |
| F027-H | 13 | 465.746 | 60.000 | -86.382 | 0.0 | 49.8 | no |
| F027-S | 13 | 464.804 | 60.000 | -87.679 | 0.0 | 119.7 | no |
| F028-H | 13 | 465.462 | 60.000 | -84.050 | 90.0 | 92.1 | ROTATE |
| F028-S | 13 | 464.267 | 60.000 | -83.599 | 0.0 | 149.7 | no |
| F029-H | 13 | 465.880 | 60.000 | -85.014 | 90.0 | 58.5 | ROTATE |
| F029-S | 13 | 466.130 | 60.000 | -82.671 | 0.0 | 47.4 | no |
| F030-H | 13 | 466.034 | 60.000 | -88.311 | 0.0 | 57.6 | no |
| F030-S | 13 | 465.593 | 60.000 | -85.423 | 0.0 | 81.0 | no |
| F031-H | 13 | 465.724 | 60.000 | -84.316 | 0.0 | 56.4 | no |
| F031-S | 13 | 465.144 | 60.000 | -84.325 | 0.0 | 80.1 | no |
| F032-H | 13 | 464.963 | 60.000 | -87.070 | 90.0 | 81.3 | ROTATE |
| F032-S | 13 | 465.647 | 60.000 | -86.731 | 0.0 | 85.5 | no |
| F033-H | 13 | 465.292 | 60.000 | -81.937 | 0.0 | 127.5 | no |
| F033-S | 13 | 464.640 | 60.000 | -78.784 | 0.0 | 146.1 | no |
| F034-H | 13 | 466.104 | 60.000 | -85.228 | 0.0 | 115.2 | no |
| F034-S | 13 | 466.051 | 60.000 | -80.712 | 0.0 | 129.3 | no |
| F035-H | 13 | 466.145 | 60.000 | -82.885 | 90.0 | 59.1 | ROTATE |
| F035-S | 13 | 465.767 | 60.000 | -83.781 | 90.0 | 58.5 | ROTATE |
| F036-H | 13 | 465.972 | 60.000 | -86.289 | 0.0 | 33.3 | no |
| F036-S | 13 | 465.975 | 60.000 | -82.199 | 0.0 | 27.9 | no |
| F037-H | 13 | 465.105 | 60.000 | -81.896 | 0.0 | 82.5 | no |
| F037-S | 13 | 465.525 | 60.000 | -86.205 | 0.0 | 126.9 | no |
| F038-H | 13 | 466.028 | 60.000 | -88.526 | 90.0 | 52.2 | ROTATE |

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|---|---|---|---|---|---|---|---|
| F038-S | 13 | 465.712 | 60.000 | -85.743 | 0.0 | 58.5 | no |
| F040-H | 13 | 466.065 | 60.000 | -85.016 | 0.0 | 40.8 | no |
| F040-S | 13 | 465.627 | 60.000 | -79.745 | 0.0 | 45.9 | no |
| F041-H | 13 | 466.131 | 60.000 | -89.958 | 0.0 | 38.1 | no |
| F041-S | 13 | 466.217 | 60.000 | -84.486 | 0.0 | 15.6 | no |
| F042-H | 13 | 465.971 | 60.000 | -97.393 | 90.0 | 51.3 | ROTATE |
| F042-S | 13 | 466.009 | 60.000 | -83.594 | 0.0 | 65.1 | no |
| F043-H | 13 | 465.911 | 60.000 | -83.628 | 0.0 | 54.3 | no |
| F043-S | 13 | 465.562 | 60.000 | -87.264 | 0.0 | 58.8 | no |
| H001-H | 13 | 466.033 | 60.000 | -92.354 | 0.0 | 56.7 | no |
| H002-H | 13 | 465.711 | 60.000 | -100.103 | 0.0 | 42.3 | no |
| H003-H | 13 | 465.974 | 60.000 | -89.432 | 0.0 | 81.9 | no |
| I001-H | 13 | 465.888 | 60.000 | -83.533 | 18.0 | 54.9 | ROTATE |
| I001-S | 13 | 464.860 | 60.000 | -83.110 | 0.0 | 86.4 | no |
| P001-H | 13 | 465.985 | 60.000 | -90.931 | 90.0 | 63.9 | ROTATE |
| P001-S | 13 | 465.161 | 60.000 | -82.167 | 0.0 | 85.2 | no |
| P002-H | 13 | 465.955 | 60.000 | -100.134 | 0.0 | 55.2 | no |
| P002-S | 13 | 466.097 | 60.000 | -87.360 | 0.0 | 91.5 | no |
| P003-H | 13 | 466.168 | 60.000 | -91.161 | 0.0 | 21.6 | no |
| P003-S | 13 | 465.943 | 60.000 | -80.700 | 0.0 | 27.6 | no |
| P004-H | 13 | 465.669 | 60.000 | -89.568 | 0.0 | 48.9 | no |
| P004-S | 13 | 464.815 | 60.000 | -84.858 | 0.0 | 89.7 | no |
| P005-H | 13 | 465.880 | 60.000 | -85.095 | 90.0 | 24.0 | ROTATE |
| P005-S | 13 | 466.095 | 60.000 | -81.893 | 90.0 | 64.2 | ROTATE |
| P006-H | 13 | 465.636 | 60.000 | -96.062 | 0.0 | 69.6 | no |
| P006-S | 13 | 466.013 | 60.000 | -83.692 | 0.0 | 36.6 | no |
| P007-H | 13 | 465.959 | 60.000 | -93.276 | 0.0 | 19.5 | no |
| P007-S | 13 | 465.958 | 60.000 | -85.830 | 0.0 | 40.8 | no |
| P008-H | 13 | 465.681 | 60.000 | -94.550 | 0.0 | 62.4 | no |
| P008-S | 13 | 466.071 | 60.000 | -92.190 | 0.0 | 75.3 | no |
| P009-H | 13 | 466.049 | 60.000 | -94.176 | 0.0 | 78.9 | no |
| P009-S | 13 | 464.559 | 60.000 | -88.280 | 0.0 | 145.2 | no |
| P010-H | 13 | 465.980 | 60.000 | -75.844 | 0.0 | 82.8 | no |
| P010-S | 13 | 465.562 | 60.000 | -82.154 | 0.0 | 65.4 | no |

## Task Room 14 Reduced Data

| File | Room | X | Y | Z | Rotate | Speed | RESULT |
|---|---|---|---|---|---|---|---|
| A001-H | 14 | 650.050 | 60.000 | -564.313 | 0.0 | 39.0 | not |
| A002-H | 14 | 651.668 | 60.000 | -564.428 | 0.0 | 40.5 | not |
| A003-H | 14 | 651.133 | 60.000 | -563.673 | 90.0 | 56.7 | not |
| A004-H | 14 | 549.797 | 60.000 | -563.367 | 0.0 | 81.0 | CATCH |
| A005-H | 14 | 650.699 | 60.000 | -564.353 | 0.0 | 32.1 | not |
| B001-H | 14 | 536.980 | 60.000 | -564.406 | 0.0 | 18.9 | CATCH |
| B001-S | 14 | 656.269 | 60.000 | -564.309 | 0.0 | 35.4 | not |
| B002-H | 14 | 545.104 | 60.000 | -564.313 | 90.0 | 36.6 | CATCH |
| B002-S | 14 | 668.314 | 60.000 | -564.403 | 0.0 | 54.6 | not |
| B003-H | 14 | 650.589 | 60.000 | -563.794 | 0.0 | 44.4 | not |
| B003-S | 14 | 653.045 | 60.000 | -563.924 | 0.0 | 63.3 | not |
| B004-H | 14 | 540.252 | 60.000 | -563.861 | 0.0 | 58.8 | CATCH |
| B004-S | 14 | 656.726 | 60.000 | -563.889 | 0.0 | 99.9 | not |
| B005-H | 14 | 638.564 | 60.000 | -564.007 | 0.0 | 51.9 | not |
| B005-S | 14 | 657.022 | 60.000 | -563.991 | 0.0 | 34.5 | not |
| F001-H | 14 | 655.893 | 60.000 | -564.243 | 0.0 | 30.0 | not |
| F001-S | 14 | 667.596 | 60.000 | -564.029 | 0.0 | 40.5 | not |
| F002-H | 14 | 547.675 | 60.000 | -564.303 | 0.0 | 73.5 | CATCH |
| F002-S | 14 | 539.520 | 60.000 | -564.096 | 0.0 | 60.0 | CATCH |
| F003-H | 14 | 648.854 | 60.000 | -564.191 | 0.0 | 51.3 | not |
| F003-S | 14 | 650.393 | 60.000 | -564.440 | 0.0 | 61.5 | not |
| F004-H | 14 | 559.817 | 60.000 | -563.936 | 0.0 | 99.3 | CATCH |

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|---|---|---|---|---|---|---|---|
| F004-S | 14 | 558.274 | 60.000 | -563.859 | 0.0 | 93.0 | CATCH |
| F005-H | 14 | 544.133 | 60.000 | -563.817 | 0.0 | 88.8 | CATCH |
| F005-S | 14 | 544.657 | 60.000 | -562.840 | 0.0 | 122.1 | CATCH |
| F006-H | 14 | 654.604 | 60.000 | -563.864 | 0.0 | 93.6 | not |
| F006-S | 14 | 658.226 | 60.000 | -564.413 | 0.0 | 62.1 | not |
| F007-H | 14 | 656.817 | 60.000 | -563.862 | 90.0 | 48.9 | not |
| F007-S | 14 | 653.642 | 60.000 | -564.405 | 93.0 | 57.9 | not |
| F008-H | 14 | 646.408 | 60.000 | -564.180 | 0.0 | 34.8 | not |
| F008-S | 14 | 651.063 | 60.000 | -564.111 | 0.0 | 36.6 | not |
| F009-H | 14 | 657.402 | 60.000 | -563.522 | 54.0 | 70.8 | not |
| F009-S | 14 | 653.913 | 94.000 | -562.601 | 0.0 | 149.4 | not |
| F010-H | 14 | 541.628 | 60.000 | -564.284 | 0.0 | 47.1 | CATCH |
| F010-S | 14 | 653.838 | 60.000 | -563.826 | 0.0 | 50.4 | not |
| F011-H | 14 | 653.098 | 60.000 | -564.017 | 0.0 | 38.1 | not |
| F011-S | 14 | 654.622 | 60.000 | -564.110 | 0.0 | 52.8 | not |
| F012-H | 14 | 650.411 | 60.000 | -563.751 | 0.0 | 88.8 | not |
| F012-S | 14 | 653.307 | 60.000 | -564.284 | 0.0 | 94.2 | not |
| F013-H | 14 | 660.289 | 60.000 | -564.092 | 0.0 | 101.1 | not |
| F013-S | 14 | 665.732 | 60.000 | -562.140 | 0.0 | 150.0 | not |
| F014-H | 14 | 650.141 | 60.000 | -564.421 | 0.0 | 60.0 | not |
| F014-S | 14 | 657.645 | 60.000 | -564.411 | 0.0 | 79.2 | not |
| F015-H | 14 | 658.256 | 60.000 | -563.874 | 0.0 | 75.6 | not |
| F015-S | 14 | 659.339 | 60.000 | -563.267 | 0.0 | 107.7 | not |
| F016-H | 14 | 648.887 | 60.000 | -564.267 | 90.0 | 33.3 | not |
| F016-S | 14 | 654.483 | 60.000 | -564.114 | 90.0 | 27.9 | not |
| F017-H | 14 | 654.311 | 60.000 | -564.179 | 0.0 | 49.5 | not |
| F017-S | 14 | 656.146 | 60.000 | -563.809 | 0.0 | 58.5 | not |
| F018-H | 14 | 648.465 | 60.000 | -564.307 | 63.0 | 48.6 | not |
| F018-S | 14 | 652.986 | 60.000 | -563.712 | 0.0 | 56.4 | not |
| F019-H | 14 | 545.689 | 60.000 | -563.468 | 39.0 | 72.0 | CATCH |
| F019-S | 14 | 661.761 | 60.000 | -563.838 | 0.0 | 66.0 | not |
| F020-H | 14 | 643.653 | 60.000 | -564.207 | 0.0 | 63.3 | not |
| F020-S | 14 | 649.638 | 60.000 | -563.910 | 0.0 | 74.1 | not |
| F021-H | 14 | 658.103 | 60.000 | -563.979 | 0.0 | 52.5 | not |
| F021-S | 14 | 656.507 | 60.000 | -563.734 | 0.0 | 117.3 | not |
| F022-H | 14 | 650.892 | 60.000 | -564.345 | 0.0 | 81.6 | not |
| F022-S | 14 | 653.492 | 60.000 | -564.082 | 0.0 | 69.9 | not |
| F023-H | 14 | 654.380 | 60.000 | -564.351 | 0.0 | 51.6 | not |
| F023-S | 14 | 660.551 | 60.000 | -563.267 | 0.0 | 96.9 | not |
| F024-H | 14 | 662.973 | 60.000 | -564.200 | 90.0 | 41.7 | not |
| F024-S | 14 | 658.245 | 60.000 | -564.095 | 0.0 | 27.3 | not |
| F025-H | 14 | 659.999 | 60.000 | -563.762 | 0.0 | 68.4 | not |
| F025-S | 14 | 666.996 | 60.000 | -564.300 | 0.0 | 80.4 | not |
| F026-H | 14 | 655.524 | 60.000 | -563.479 | 0.0 | 89.4 | not |
| F026-S | 14 | 656.884 | 60.000 | -563.140 | 0.0 | 83.1 | not |
| F027-H | 14 | 656.093 | 60.000 | -563.884 | 0.0 | 74.4 | not |
| F027-S | 14 | 653.867 | 60.000 | -562.928 | 0.0 | 99.6 | not |
| F028-H | 14 | 648.351 | 60.000 | -564.260 | 0.0 | 111.3 | not |
| F028-S | 14 | 664.922 | 60.000 | -563.447 | 0.0 | 92.1 | not |
| F029-H | 14 | 649.515 | 60.000 | -563.796 | 0.0 | 57.3 | not |
| F029-S | 14 | 653.513 | 60.000 | -564.021 | 0.0 | 42.6 | not |
| F030-H | 14 | 651.425 | 60.000 | -563.820 | 0.0 | 62.1 | not |
| F030-S | 14 | 661.321 | 60.000 | -563.854 | 0.0 | 80.4 | not |
| F031-H | 14 | 649.990 | 60.000 | -564.350 | 0.0 | 36.3 | not |
| F031-S | 14 | 656.936 | 60.000 | -564.288 | 0.0 | 54.9 | not |
| F032-H | 14 | 649.804 | 60.000 | -564.406 | 0.0 | 82.8 | not |
| F032-S | 14 | 652.745 | 60.000 | -564.024 | 0.0 | 82.5 | not |
| F033-H | 14 | 655.805 | 60.000 | -563.923 | 0.0 | 45.6 | not |
| F033-S | 14 | 655.207 | 60.000 | -563.812 | 0.0 | 107.1 | not |
| F034-H | 14 | 652.197 | 60.000 | -562.793 | 0.0 | 120.3 | not |

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|---|---|---|---|---|---|---|---|
| F034-S | 14 | 657.855 | 60.000 | -563.727 | 0.0 | 125.7 | not |
| F035-H | 14 | 660.618 | 60.000 | -564.141 | 90.0 | 49.8 | not |
| F035-S | 14 | 657.761 | 60.000 | -564.061 | 0.0 | 52.2 | not |
| F036-H | 14 | 652.706 | 60.000 | -564.436 | 0.0 | 39.9 | not |
| F036-S | 14 | 654.939 | 60.000 | -564.157 | 0.0 | 29.4 | not |
| F037-H | 14 | 662.130 | 60.000 | -563.774 | 0.0 | 58.5 | not |
| F037-S | 14 | 662.682 | 60.000 | -564.320 | 0.0 | 117.6 | not |
| F038-H | 14 | 658.665 | 60.000 | -564.022 | 0.0 | 56.7 | not |
| F038-S | 14 | 667.359 | 60.000 | -564.470 | 0.0 | 72.3 | not |
| F040-H | 14 | 647.781 | 60.000 | -563.808 | 0.0 | 51.9 | not |
| F040-S | 14 | 656.453 | 60.000 | -564.261 | 0.0 | 47.1 | not |
| F041-H | 14 | 542.276 | 60.000 | -564.477 | 0.0 | 33.6 | CATCH |
| F041-S | 14 | 545.255 | 60.000 | -564.431 | 0.0 | 53.7 | CATCH |
| F042-H | 14 | 646.487 | 60.000 | -563.906 | 0.0 | 42.0 | not |
| F042-S | 14 | 651.778 | 60.000 | -563.951 | 0.0 | 67.5 | not |
| F043-H | 14 | 652.694 | 60.000 | -563.983 | 0.0 | 42.6 | not |
| F043-S | 14 | 654.118 | 60.000 | -564.480 | 0.0 | 69.6 | not |
| H001-H | 14 | 661.177 | 60.000 | -563.581 | 0.0 | 60.3 | not |
| H002-H | 14 | 657.881 | 60.000 | -564.392 | 0.0 | 53.4 | not |
| H003-H | 14 | 654.244 | 60.000 | -563.484 | 0.0 | 85.8 | not |
| I001-H | 14 | 655.009 | 60.000 | -564.458 | 0.0 | 84.9 | not |
| I001-S | 14 | 656.749 | 60.000 | -564.455 | 0.0 | 91.8 | not |
| P001-H | 14 | 646.135 | 60.000 | -564.174 | 90.0 | 68.7 | not |
| P001-S | 14 | 654.043 | 60.000 | -563.545 | 0.0 | 64.5 | not |
| P002-H | 14 | 655.437 | 60.000 | -564.084 | 0.0 | 53.4 | not |
| P002-S | 14 | 664.957 | 60.000 | -564.034 | 0.0 | 71.4 | not |
| P003-H | 14 | 657.944 | 60.000 | -564.251 | 0.0 | 25.5 | not |
| P003-S | 14 | 668.880 | 60.000 | -564.293 | 0.0 | 29.1 | not |
| P004-H | 14 | 661.895 | 60.000 | -564.009 | 0.0 | 57.0 | not |
| P004-S | 14 | 663.948 | 60.000 | -564.325 | 0.0 | 59.7 | not |
| P005-H | 14 | 651.025 | 60.000 | -564.063 | 90.0 | 30.3 | not |
| P005-S | 14 | 653.394 | 60.000 | -564.004 | 90.0 | 32.7 | not |
| P006-H | 14 | 655.894 | 60.000 | -563.481 | 0.0 | 83.7 | not |
| P006-S | 14 | 661.311 | 60.000 | -563.959 | 0.0 | 48.0 | not |
| P007-H | 14 | 650.244 | 60.000 | -564.257 | 0.0 | 23.1 | not |
| P007-S | 14 | 661.283 | 60.000 | -563.770 | 0.0 | 49.8 | not |
| P008-H | 14 | 656.638 | 60.000 | -564.375 | 0.0 | 70.2 | not |
| P008-S | 14 | 668.530 | 60.000 | -564.249 | 0.0 | 136.2 | not |
| P009-H | 14 | 646.292 | 60.000 | -564.147 | 0.0 | 85.2 | not |
| P009-S | 14 | 647.071 | 60.000 | -564.042 | 0.0 | 145.8 | not |
| P010-H | 14 | 663.966 | 60.000 | -563.673 | 0.0 | 81.3 | not |
| P010-S | 14 | 664.589 | 60.000 | -563.874 | 0.0 | 55.2 | not |

## Task Room 15 Reduced Data

| File | Room | X | Y | Z | Rotate | Speed | RESULT |
|---|---|---|---|---|---|---|---|
| A001-H | 15 | 1055.023 | 125.000 | -719.432 | 0.0 | 46.2 | FLY |
| A002-H | 15 | 1054.582 | 60.000 | -617.742 | 0.0 | 76.5 | no |
| A003-H | 15 | 1055.234 | 60.000 | -616.508 | 0.0 | 36.6 | no |
| A004-H | 15 | 1054.928 | 125.000 | -719.589 | 0.0 | 81.0 | FLY |
| A005-H | 15 | 1055.074 | 125.000 | -703.650 | 0.0 | 48.9 | FLY |
| B001-H | 15 | 1055.586 | 60.000 | -717.300 | 0.0 | 15.9 | no |
| B001-S | 15 | 1055.640 | 60.000 | -617.025 | 0.0 | 18.6 | no |
| B002-H | 15 | 1055.544 | 60.000 | -616.396 | 0.0 | 61.2 | no |
| B002-S | 15 | 1055.185 | 125.000 | -713.514 | 0.0 | 62.1 | FLY |
| B003-H | 15 | 1055.307 | 60.000 | -714.455 | 90.0 | 51.9 | m/b |
| B003-S | 15 | 1055.180 | 121.000 | -714.348 | 0.0 | 66.9 | FLY |
| B004-H | 15 | 1055.236 | 60.000 | -624.874 | 0.0 | 57.0 | no |
| B004-S | 15 | 1054.489 | 125.000 | -714.642 | 0.0 | 83.7 | FLY |
| B005-H | 15 | 1055.573 | 60.000 | -634.666 | 0.0 | 24.9 | no |

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|---|---|---|---|---|---|---|---|
| B005-S | 15 | 1055.497 | 60.000 | -629.263 | 0.0 | 23.7 | no |
| F001-H | 15 | 1055.523 | 119.000 | -709.297 | 0.0 | 21.6 | FLY |
| F001-S | 15 | 1055.191 | 125.000 | -719.699 | 0.0 | 49.2 | FLY |
| F002-H | 15 | 1054.824 | 60.000 | -625.009 | 0.0 | 88.5 | no |
| F002-S | 15 | 1054.880 | 125.000 | -708.678 | 0.0 | 59.1 | FLY |
| F003-H | 15 | 1054.870 | 125.000 | -705.937 | 0.0 | 78.9 | FLY |
| F003-S | 15 | 1055.310 | 125.000 | -709.341 | 0.0 | 94.5 | FLY |
| F004-H | 15 | 1054.753 | 60.000 | -618.161 | 0.0 | 109.5 | no |
| F004-S | 15 | 1055.129 | 88.000 | -718.105 | 0.0 | 86.1 | FLY |
| F005-H | 15 | 1054.934 | 125.000 | -701.056 | 0.0 | 113.4 | FLY |
| F005-S | 15 | 1055.067 | 119.000 | -702.714 | 0.0 | 132.3 | FLY |
| F006-H | 15 | 1054.513 | 123.000 | -711.656 | 0.0 | 103.2 | FLY |
| F006-S | 15 | 1055.225 | 125.000 | -715.583 | 0.0 | 81.0 | FLY |
| F007-H | 15 | 1054.926 | 125.000 | -709.742 | 0.0 | 60.9 | FLY |
| F007-S | 15 | 1055.442 | 125.000 | -708.236 | 0.0 | 59.1 | FLY |
| F008-H | 15 | 1055.400 | 125.000 | -712.300 | 0.0 | 44.4 | FLY |
| F008-S | 15 | 1055.074 | 125.000 | -711.343 | 0.0 | 44.4 | FLY |
| F009-H | 15 | 1054.938 | 60.000 | -621.012 | 90.0 | 75.6 | m/b |
| F009-S | 15 | 1055.084 | 108.000 | -713.506 | 0.0 | 145.8 | FLY |
| F010-H | 15 | 1055.610 | 125.000 | -719.096 | 0.0 | 55.5 | FLY |
| F010-S | 15 | 1054.940 | 125.000 | -723.580 | 0.0 | 60.6 | FLY |
| F011-H | 15 | 1055.643 | 60.000 | -625.178 | 0.0 | 24.0 | no |
| F011-S | 15 | 1055.669 | 125.000 | -710.241 | 0.0 | 51.6 | FLY |
| F012-H | 15 | 1054.783 | 125.000 | -703.176 | 0.0 | 90.9 | FLY |
| F012-S | 15 | 1054.841 | 125.000 | -701.205 | 0.0 | 97.2 | FLY |
| F013-H | 15 | 1055.646 | 125.000 | -714.302 | 0.0 | 95.7 | FLY |
| F013-S | 15 | 1053.825 | 60.000 | -626.180 | 0.0 | 146.7 | no |
| F014-H | 15 | 1055.415 | 60.000 | -617.367 | 0.0 | 63.0 | no |
| F014-S | 15 | 1055.667 | 125.000 | -710.484 | 0.0 | 82.8 | FLY |
| F015-H | 15 | 1055.449 | 125.000 | -709.302 | 0.0 | 73.2 | FLY |
| F015-S | 15 | 1054.840 | 125.000 | -708.683 | 0.0 | 124.8 | FLY |
| F016-H | 15 | 1055.308 | 125.000 | -712.225 | 0.0 | 33.0 | FLY |
| F016-S | 15 | 1055.614 | 60.000 | -619.542 | 90.0 | 19.5 | m/b |
| F017-H | 15 | 1055.273 | 125.000 | -702.579 | 0.0 | 42.3 | FLY |
| F017-S | 15 | 1055.270 | 125.000 | -715.413 | 0.0 | 53.7 | FLY |
| F018-H | 15 | 1055.314 | 125.000 | -707.044 | 0.0 | 51.0 | FLY |
| F018-S | 15 | 1055.530 | 125.000 | -708.367 | 0.0 | 59.4 | FLY |
| F019-H | 15 | 1054.742 | 101.000 | -714.144 | 0.0 | 73.2 | FLY |
| F019-S | 15 | 1055.419 | 125.000 | -718.447 | 0.0 | 78.6 | FLY |
| F020-H | 15 | 1055.154 | 125.000 | -708.721 | 0.0 | 62.1 | FLY |
| F020-S | 15 | 1055.749 | 60.000 | -618.158 | 0.0 | 67.5 | no |
| F021-H | 15 | 1055.232 | 60.000 | -616.024 | 0.0 | 67.2 | no |
| F021-S | 15 | 1054.918 | 125.000 | -708.501 | 0.0 | 103.8 | FLY |
| F022-H | 15 | 1055.717 | 60.000 | -618.607 | 0.0 | 91.8 | no |
| F022-S | 15 | 1055.408 | 60.000 | -621.945 | 0.0 | 94.5 | no |
| F023-H | 15 | 1055.436 | 125.000 | -705.489 | 0.0 | 51.9 | FLY |
| F023-S | 15 | 1055.484 | 125.000 | -715.622 | 0.0 | 96.3 | FLY |
| F024-H | 15 | 1055.145 | 125.000 | -710.240 | 0.0 | 48.0 | FLY |
| F024-S | 15 | 1055.205 | 125.000 | -711.571 | 0.0 | 43.5 | FLY |
| F025-H | 15 | 1055.620 | 125.000 | -712.367 | 0.0 | 54.6 | FLY |
| F025-S | 15 | 1055.033 | 125.000 | -720.402 | 0.0 | 60.6 | FLY |
| F026-H | 15 | 1055.707 | 60.000 | -621.357 | 0.0 | 83.7 | no |
| F026-S | 15 | 1054.902 | 125.000 | -716.411 | 0.0 | 80.4 | FLY |
| F027-H | 15 | 1055.725 | 125.000 | -703.516 | 0.0 | 51.0 | FLY |
| F027-S | 15 | 1055.183 | 125.000 | -702.128 | 0.0 | 112.8 | FLY |
| F028-H | 15 | 1055.665 | 60.000 | -620.608 | 0.0 | 87.0 | no |
| F028-S | 15 | 1055.444 | 60.000 | -621.434 | 0.0 | 68.4 | no |
| F029-H | 15 | 1054.896 | 60.000 | -615.877 | 0.0 | 60.9 | no |
| F029-S | 15 | 1055.037 | 125.000 | -713.544 | 0.0 | 64.8 | FLY |
| F030-H | 15 | 1055.219 | 125.000 | -702.626 | 0.0 | 46.2 | FLY |

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|---|---|---|---|---|---|---|---|
| F030-S | 15 | 1054.728 | 125.000 | -702.597 | 0.0 | 69.0 | FLY |
| F031-H | 15 | 1055.081 | 60.000 | -619.929 | 0.0 | 42.3 | no |
| F031-S | 15 | 1054.490 | 60.000 | -614.488 | 0.0 | 80.7 | no |
| F032-H | 15 | 1054.713 | 125.000 | -713.565 | 0.0 | 90.0 | FLY |
| F032-S | 15 | 1055.513 | 60.000 | -628.875 | 0.0 | 85.2 | no |
| F033-H | 15 | 1053.761 | 116.000 | -724.922 | 0.0 | 120.0 | FLY |
| F033-S | 15 | 1054.088 | 100.000 | -723.589 | 0.0 | 126.6 | FLY |
| F034-H | 15 | 1054.556 | 125.000 | -706.938 | 0.0 | 123.9 | FLY |
| F034-S | 15 | 1055.372 | 60.000 | -617.730 | 0.0 | 122.7 | no |
| F035-H | 15 | 1055.316 | 60.000 | -620.072 | 90.0 | 34.8 | m/b |
| F035-S | 15 | 1055.662 | 81.000 | -713.897 | 0.0 | 24.6 | FLY |
| F036-H | 15 | 1055.617 | 125.000 | -715.801 | 0.0 | 30.6 | FLY |
| F036-S | 15 | 1055.292 | 125.000 | -717.283 | 0.0 | 29.1 | FLY |
| F037-H | 15 | 1054.719 | 119.000 | -713.498 | 0.0 | 75.6 | FLY |
| F037-S | 15 | 1054.860 | 125.000 | -714.017 | 0.0 | 74.7 | FLY |
| F038-H | 15 | 1055.118 | 60.000 | -711.897 | 0.0 | 60.9 | no |
| F038-S | 15 | 1054.954 | 60.000 | -719.605 | 0.0 | 78.0 | no |
| F040-H | 15 | 1055.605 | 60.000 | -624.281 | 0.0 | 50.4 | no |
| F040-S | 15 | 1055.369 | 125.000 | -708.650 | 0.0 | 51.9 | FLY |
| F041-H | 15 | 1055.729 | 60.000 | -625.032 | 0.0 | 16.5 | no |
| F041-S | 15 | 1055.440 | 60.000 | -714.250 | 0.0 | 53.7 | no |
| F042-H | 15 | 1055.551 | 60.000 | -622.129 | 0.0 | 41.4 | no |
| F042-S | 15 | 1055.458 | 60.000 | -623.332 | 0.0 | 55.8 | no |
| F043-H | 15 | 1055.196 | 125.000 | -708.863 | 0.0 | 50.1 | FLY |
| F043-S | 15 | 1054.696 | 125.000 | -708.663 | 0.0 | 69.3 | FLY |
| H001-H | 15 | 1054.993 | 60.000 | -624.252 | 0.0 | 62.4 | no |
| H002-H | 15 | 1055.476 | 60.000 | -623.697 | 0.0 | 34.8 | no |
| H003-H | 15 | 1055.037 | 60.000 | -621.142 | 0.0 | 66.9 | no |
| I001-H | 15 | 1055.012 | 95.000 | -714.294 | 0.0 | 62.4 | FLY |
| I001-S | 15 | 1055.531 | 74.000 | -723.837 | 0.0 | 85.2 | FLY |
| P001-H | 15 | 1054.555 | 60.000 | -622.658 | 36.0 | 79.2 | m/b |
| P001-S | 15 | 1055.297 | 160.000 | -708.000 | 0.0 | 77.4 | FLY |
| P002-H | 15 | 1054.931 | 60.000 | -623.222 | 0.0 | 60.3 | no |
| P002-S | 15 | 1054.832 | 60.000 | -714.763 | 90.0 | 87.6 | m/b |
| P003-H | 15 | 1055.517 | 60.000 | -622.760 | 0.0 | 16.8 | no |
| P003-S | 15 | 1055.562 | 60.000 | -605.712 | 0.0 | 23.4 | no |
| P004-H | 15 | 1055.442 | 60.000 | -635.756 | 90.0 | 49.2 | m/b |
| P004-S | 15 | 1055.525 | 60.000 | -618.383 | 0.0 | 32.7 | no |
| P005-H | 15 | 1055.496 | 210.000 | -707.825 | 0.0 | 18.9 | FLY |
| P005-S | 15 | 1055.041 | 112.000 | -713.392 | 0.0 | 42.9 | FLY |
| P006-H | 15 | 1055.664 | 164.000 | -699.736 | 0.0 | 72.6 | FLY |
| P006-S | 15 | 1055.506 | 60.000 | -615.844 | 0.0 | 65.4 | no |
| P007-H | 15 | 1055.484 | 60.000 | -623.882 | 90.0 | 21.6 | m/b |
| P007-S | 15 | 1055.315 | 252.000 | -710.261 | 0.0 | 35.7 | FLY |
| P008-H | 15 | 1054.864 | 60.000 | -630.921 | 0.0 | 68.4 | no |
| P008-S | 15 | 1054.879 | 236.000 | -702.533 | 0.0 | 65.4 | FLY |
| P009-H | 15 | 1055.307 | 156.000 | -704.920 | 0.0 | 85.8 | FLY |
| P009-S | 15 | 1054.525 | 124.000 | -710.049 | 0.0 | 146.7 | FLY |
| P010-H | 15 | 1055.690 | 60.000 | -625.746 | 0.0 | 72.6 | no |
| P010-S | 15 | 1055.310 | 60.000 | -625.029 | 0.0 | 61.5 | no |

## Task Room 16 Reduced Data

| File | Room | X | Y | Z | Rotate | Speed | RESULT |
|---|---|---|---|---|---|---|---|
| A001-H | 16 | 1194.963 | 60.000 | -222.495 | 72.0 | 70.2 | ROTATE |
| A002-H | 16 | 1192.719 | 60.000 | -222.417 | 84.0 | 70.8 | ROTATE |
| A003-H | 16 | 1192.842 | 60.000 | -222.122 | 90.0 | 58.8 | ROTATE |
| A004-H | 16 | 1197.894 | 60.000 | -222.089 | 0.0 | 144.9 | no |
| A005-H | 16 | 1194.634 | 60.000 | -221.617 | 90.0 | 82.2 | ROTATE |
| B001-H | 16 | 1200.035 | 60.000 | -221.571 | 0.0 | 11.7 | no |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| B001-S | 16 | 1192.351 | 60.000 | -221.586 | 0.0 | 20.7 | no |
| B002-H | 16 | 1200.767 | 60.000 | -222.072 | 0.0 | 63.6 | no |
| B002-S | 16 | 1193.532 | 60.000 | -222.721 | 90.0 | 91.5 | ROTATE |
| B003-H | 16 | 1201.819 | 60.000 | -222.084 | 0.0 | 58.5 | no |
| B003-S | 16 | 1192.583 | 60.000 | -222.066 | 0.0 | 72.9 | no |
| B004-H | 16 | 1196.085 | 60.000 | -221.880 | 0.0 | 40.5 | no |
| B004-S | 16 | 1195.158 | 60.000 | -222.251 | 90.0 | 74.4 | ROTATE |
| B005-H | 16 | 1207.162 | 60.000 | -221.716 | 0.0 | 31.5 | no |
| B005-S | 16 | 1194.427 | 60.000 | -222.091 | 0.0 | 45.9 | no |
| F001-H | 16 | 1192.687 | 60.000 | -221.645 | 90.0 | 27.9 | ROTATE |
| F001-S | 16 | 1192.041 | 60.000 | -222.391 | 90.0 | 58.8 | ROTATE |
| F002-H | 16 | 1192.385 | 60.000 | -222.140 | 90.0 | 89.1 | ROTATE |
| F002-S | 16 | 1188.959 | 60.000 | -221.866 | 90.0 | 82.2 | ROTATE |
| F003-H | 16 | 1198.751 | 60.000 | -222.452 | 90.0 | 78.3 | ROTATE |
| F003-S | 16 | 1196.918 | 60.000 | -221.510 | 90.0 | 103.5 | ROTATE |
| F004-H | 16 | 1188.780 | 60.000 | -222.445 | 0.0 | 123.9 | no |
| F004-S | 16 | 1194.593 | 60.000 | -222.389 | 0.0 | 82.2 | no |
| F005-H | 16 | 1193.845 | 60.000 | -221.717 | 90.0 | 79.8 | ROTATE |
| F005-S | 16 | 1197.243 | 60.000 | -221.852 | 33.0 | 123.6 | ROTATE |
| F006-H | 16 | 1198.725 | 60.000 | -222.589 | 90.0 | 119.1 | ROTATE |
| F006-S | 16 | 1193.055 | 60.000 | -222.554 | 90.0 | 84.3 | ROTATE |
| F007-H | 16 | 1195.560 | 60.000 | -221.605 | 90.0 | 75.0 | ROTATE |
| F007-S | 16 | 1194.526 | 60.000 | -221.508 | 90.0 | 74.4 | ROTATE |
| F008-H | 16 | 1196.412 | 60.000 | -221.718 | 15.0 | 41.1 | no |
| F008-S | 16 | 1195.291 | 60.000 | -221.589 | 90.0 | 29.1 | ROTATE |
| F009-H | 16 | 1189.601 | 60.000 | -222.201 | 90.0 | 43.8 | ROTATE |
| F009-S | 16 | 1193.380 | 60.000 | -222.227 | 60.0 | 150.0 | ROTATE |
| F010-H | 16 | 1195.504 | 60.000 | -222.040 | 90.0 | 67.5 | ROTATE |
| F010-S | 16 | 1192.569 | 60.000 | -221.730 | 90.0 | 74.1 | ROTATE |
| F011-H | 16 | 1191.089 | 60.000 | -221.881 | 90.0 | 37.2 | ROTATE |
| F011-S | 16 | 1193.959 | 60.000 | -221.730 | 90.0 | 54.6 | ROTATE |
| F012-H | 16 | 1191.594 | 60.000 | -221.819 | 0.0 | 74.1 | no |
| F012-S | 16 | 1189.527 | 60.000 | -221.732 | 0.0 | 93.0 | no |
| F013-H | 16 | 1197.628 | 60.000 | -222.952 | 90.0 | 90.9 | ROTATE |
| F013-S | 16 | 1194.748 | 60.000 | -221.948 | 0.0 | 130.2 | no |
| F014-H | 16 | 1192.150 | 60.000 | -221.823 | 0.0 | 62.7 | no |
| F014-S | 16 | 1196.195 | 60.000 | -221.942 | 93.0 | 80.4 | ROTATE |
| F015-H | 16 | 1192.701 | 60.000 | -222.458 | 90.0 | 72.9 | ROTATE |
| F015-S | 16 | 1193.094 | 60.000 | -222.336 | 90.0 | 108.6 | ROTATE |
| F016-H | 16 | 1193.245 | 60.000 | -221.747 | 90.0 | 33.9 | ROTATE |
| F016-S | 16 | 1194.211 | 60.000 | -221.676 | 90.0 | 19.2 | ROTATE |
| F017-H | 16 | 1195.072 | 60.000 | -221.635 | 90.0 | 52.2 | ROTATE |
| F017-S | 16 | 1194.964 | 60.000 | -222.004 | 63.0 | 65.1 | ROTATE |
| F018-H | 16 | 1194.673 | 60.000 | -221.934 | 90.0 | 48.3 | ROTATE |
| F018-S | 16 | 1196.683 | 60.000 | -221.787 | 90.0 | 54.0 | ROTATE |
| F019-H | 16 | 1192.809 | 60.000 | -222.221 | 90.0 | 59.1 | ROTATE |
| F019-S | 16 | 1192.977 | 60.000 | -221.638 | 90.0 | 107.1 | ROTATE |
| F020-H | 16 | 1192.220 | 60.000 | -221.852 | 90.0 | 81.3 | ROTATE |
| F020-S | 16 | 1193.046 | 60.000 | -222.407 | 90.0 | 70.5 | ROTATE |
| F021-H | 16 | 1190.536 | 60.000 | -222.484 | 90.0 | 88.5 | ROTATE |
| F021-S | 16 | 1190.891 | 60.000 | -222.703 | 66.0 | 118.5 | ROTATE |
| F022-H | 16 | 1200.134 | 60.000 | -222.982 | 90.0 | 107.7 | ROTATE |
| F022-S | 16 | 1198.055 | 60.000 | -222.388 | 36.0 | 97.2 | ROTATE |
| F023-H | 16 | 1192.149 | 60.000 | -221.891 | 0.0 | 50.1 | no |
| F023-S | 16 | 1192.665 | 60.000 | -222.954 | 87.0 | 87.6 | ROTATE |
| F024-H | 16 | 1195.946 | 60.000 | -221.813 | 90.0 | 47.7 | ROTATE |
| F024-S | 16 | 1194.443 | 60.000 | -221.835 | 90.0 | 56.4 | ROTATE |
| F025-H | 16 | 1196.223 | 60.000 | -221.933 | 90.0 | 65.4 | ROTATE |
| F025-S | 16 | 1195.668 | 60.000 | -221.835 | 78.0 | 64.2 | ROTATE |
| F026-H | 16 | 1194.393 | 60.000 | -223.041 | 87.0 | 91.8 | ROTATE |

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|---|---|---|---|---|---|---|---|
| F026-S | 16 | 1194.543 | 60.000 | -222.792 | 90.0 | 83.7 | ROTATE |
| F027-H | 16 | 1192.735 | 60.000 | -222.262 | 90.0 | 55.5 | ROTATE |
| F027-S | 16 | 1192.055 | 60.000 | -222.549 | 0.0 | 116.7 | no |
| F028-H | 16 | 1194.961 | 60.000 | -221.998 | 90.0 | 84.0 | ROTATE |
| F028-S | 16 | 1194.240 | 60.000 | -221.615 | 84.0 | 62.7 | ROTATE |
| F029-H | 16 | 1196.326 | 60.000 | -222.601 | 90.0 | 68.7 | ROTATE |
| F029-S | 16 | 1195.556 | 60.000 | -221.796 | 90.0 | 54.0 | ROTATE |
| F030-H | 16 | 1193.785 | 60.000 | -222.422 | 90.0 | 56.1 | ROTATE |
| F030-S | 16 | 1193.890 | 60.000 | -221.877 | 90.0 | 63.3 | ROTATE |
| F031-H | 16 | 1193.546 | 60.000 | -222.059 | 18.0 | 43.2 | ROTATE |
| F031-S | 16 | 1192.939 | 60.000 | -222.688 | 75.0 | 80.1 | ROTATE |
| F032-H | 16 | 1194.985 | 60.000 | -223.156 | 45.0 | 109.8 | ROTATE |
| F032-S | 16 | 1190.864 | 60.000 | -222.344 | 90.0 | 90.9 | ROTATE |
| F033-H | 16 | 1198.287 | 60.000 | -222.543 | 90.0 | 145.2 | ROTATE |
| F033-S | 16 | 1197.277 | 60.000 | -222.274 | 0.0 | 147.3 | no |
| F034-H | 16 | 1192.416 | 60.000 | -222.760 | 90.0 | 127.2 | ROTATE |
| F034-S | 16 | 1195.430 | 60.000 | -222.853 | 90.0 | 124.8 | ROTATE |
| F035-H | 16 | 1192.517 | 60.000 | -221.526 | 90.0 | 37.2 | ROTATE |
| F035-S | 16 | 1193.103 | 60.000 | -221.691 | 90.0 | 43.2 | ROTATE |
| F036-H | 16 | 1195.850 | 60.000 | -221.976 | 0.0 | 42.6 | no |
| F036-S | 16 | 1198.958 | 60.000 | -222.220 | 90.0 | 45.6 | ROTATE |
| F037-H | 16 | 1196.935 | 60.000 | -222.123 | 90.0 | 71.1 | ROTATE |
| F037-S | 16 | 1193.258 | 60.000 | -222.806 | 75.0 | 111.9 | ROTATE |
| F038-H | 16 | 1198.201 | 60.000 | -222.675 | 90.0 | 69.6 | ROTATE |
| F038-S | 16 | 1204.368 | 60.000 | -221.566 | 90.0 | 64.2 | ROTATE |
| F040-H | 16 | 1192.665 | 60.000 | -222.076 | 0.0 | 59.1 | no |
| F040-S | 16 | 1195.967 | 60.000 | -222.227 | 0.0 | 49.5 | no |
| F041-H | 16 | 1190.292 | 60.000 | -221.519 | 0.0 | 20.7 | no |
| F041-S | 16 | 1191.061 | 60.000 | -221.616 | 90.0 | 43.2 | ROTATE |
| F042-H | 16 | 1194.796 | 60.000 | -222.186 | 90.0 | 41.4 | ROTATE |
| F042-S | 16 | 1194.752 | 60.000 | -222.003 | 0.0 | 55.8 | no |
| F043-H | 16 | 1193.021 | 60.000 | -221.868 | 0.0 | 46.8 | no |
| F043-S | 16 | 1193.885 | 60.000 | -221.847 | 0.0 | 53.1 | no |
| H001-H | 16 | 1193.920 | 60.000 | -222.186 | 90.0 | 42.3 | ROTATE |
| H002-H | 16 | 1193.042 | 60.000 | -221.807 | 0.0 | 42.3 | no |
| H003-H | 16 | 1259.446 | 60.000 | -221.557 | 0.0 | 80.4 | no |
| I001-H | 16 | 1191.226 | 60.000 | -222.549 | 90.0 | 89.1 | ROTATE |
| I001-S | 16 | 1195.286 | 60.000 | -221.685 | 90.0 | 85.5 | ROTATE |
| P001-H | 16 | 1195.000 | 60.000 | -222.584 | 90.0 | 78.9 | ROTATE |
| P001-S | 16 | 1195.944 | 60.000 | -221.593 | 90.0 | 65.4 | ROTATE |
| P002-H | 16 | 1194.076 | 60.000 | -222.607 | 90.0 | 69.6 | ROTATE |
| P002-S | 16 | 1197.198 | 60.000 | -222.269 | 90.0 | 62.4 | ROTATE |
| P003-H | 16 | 1194.345 | 60.000 | -221.654 | 90.0 | 18.9 | ROTATE |
| P003-S | 16 | 1197.878 | 60.000 | -221.688 | 90.0 | 43.5 | ROTATE |
| P004-H | 16 | 1192.167 | 60.000 | -221.830 | 90.0 | 54.9 | ROTATE |
| P004-S | 16 | 1193.429 | 60.000 | -221.672 | 63.0 | 26.4 | ROTATE |
| P005-H | 16 | 1194.516 | 60.000 | -221.925 | 90.0 | 44.1 | ROTATE |
| P005-S | 16 | 1193.548 | 60.000 | -222.333 | 90.0 | 57.3 | ROTATE |
| P006-H | 16 | 1191.039 | 60.000 | -221.776 | 0.0 | 25.8 | no |
| P006-S | 16 | 1194.755 | 60.000 | -222.141 | 0.0 | 46.8 | no |
| P007-H | 16 | 1194.039 | 60.000 | -221.534 | 90.0 | 49.8 | ROTATE |
| P007-S | 16 | 1193.847 | 60.000 | -221.589 | 90.0 | 31.8 | ROTATE |
| P008-H | 16 | 1198.181 | 60.000 | -222.320 | 0.0 | 58.8 | no |
| P008-S | 16 | 1194.539 | 60.000 | -222.422 | 0.0 | 67.8 | no |
| P009-H | 16 | 1193.603 | 60.000 | -222.274 | 0.0 | 99.3 | no |
| P009-S | 16 | 1185.590 | 60.000 | -223.444 | 0.0 | 150.0 | no |
| P010-H | 16 | 1196.419 | 60.000 | -222.183 | 0.0 | 83.1 | no |
| P010-S | 16 | 1198.429 | 60.000 | -221.838 | 0.0 | 60.3 | no |

## Task Room 17 Reduced Data

| File | Room | X | Y | Z | Rotate | Speed | RESULT |
|---:|---:|---:|---:|---:|---:|---:|---:|
| A001-H | 17 | 1644.680 | 60.000 | -147.935 | 0.0 | 67.8 | CATCH |
| A002-H | 17 | 1644.861 | 60.000 | -144.577 | 0.0 | 66.0 | CATCH |
| A003-H | 17 | 1644.765 | 60.000 | -151.049 | 0.0 | 41.4 | CATCH |
| A004-H | 17 | 1644.117 | 60.000 | -145.962 | 0.0 | 79.5 | CATCH |
| A005-H | 17 | 1645.155 | 60.000 | -142.910 | 0.0 | 34.2 | CATCH |
| B001-H | 17 | 1645.109 | 60.000 | -145.229 | 0.0 | 10.2 | CATCH |
| B001-S | 17 | 1644.982 | 60.000 | -30.987 | 0.0 | 16.5 | not |
| B002-H | 17 | 1645.052 | 60.000 | -145.934 | 0.0 | 46.5 | CATCH |
| B002-S | 17 | 1645.151 | 60.000 | -16.838 | 0.0 | 66.3 | not |
| B003-H | 17 | 1644.482 | 60.000 | -150.553 | 0.0 | 57.6 | CATCH |
| B003-S | 17 | 1645.041 | 60.000 | -23.170 | 0.0 | 70.5 | not |
| B004-H | 17 | 1644.425 | 60.000 | -148.411 | 0.0 | 55.5 | CATCH |
| B004-S | 17 | 1645.003 | 60.000 | -29.192 | 0.0 | 87.9 | not |
| B005-H | 17 | 1645.086 | 60.000 | -153.279 | 0.0 | 31.5 | CATCH |
| B005-S | 17 | 1644.952 | 60.000 | -33.289 | 0.0 | 38.7 | not |
| F001-H | 17 | 1644.602 | 60.000 | -30.433 | 0.0 | 46.8 | not |
| F001-S | 17 | 1644.932 | 60.000 | -15.166 | 0.0 | 49.8 | not |
| F002-H | 17 | 1644.536 | 60.000 | -150.095 | 0.0 | 89.1 | CATCH |
| F002-S | 17 | 1645.100 | 60.000 | -41.602 | 0.0 | 62.7 | not |
| F003-H | 17 | 1644.109 | 60.000 | -146.346 | 0.0 | 70.2 | CATCH |
| F003-S | 17 | 1644.807 | 60.000 | -135.098 | 0.0 | 84.9 | CATCH |
| F004-H | 17 | 1644.038 | 60.000 | -144.606 | 0.0 | 89.7 | CATCH |
| F004-S | 17 | 1645.182 | 60.000 | -154.464 | 0.0 | 69.0 | CATCH |
| F005-H | 17 | 1645.156 | 60.000 | -42.056 | 0.0 | 66.6 | not |
| F005-S | 17 | 1643.671 | 60.000 | -137.462 | 0.0 | 120.9 | CATCH |
| F006-H | 17 | 1644.182 | 60.000 | -141.669 | 0.0 | 127.8 | CATCH |
| F006-S | 17 | 1644.646 | 60.000 | -144.378 | 0.0 | 77.4 | CATCH |
| F007-H | 17 | 1644.912 | 60.000 | -31.591 | 90.0 | 52.5 | not |
| F007-S | 17 | 1644.822 | 60.000 | -28.943 | 0.0 | 63.3 | not |
| F008-H | 17 | 1645.156 | 60.000 | -27.181 | 0.0 | 43.8 | not |
| F008-S | 17 | 1645.168 | 60.000 | -27.123 | 0.0 | 52.2 | not |
| F009-H | 17 | 1645.229 | 60.000 | -40.449 | 75.0 | 95.7 | not |
| F009-S | 17 | 1644.945 | 60.000 | -28.459 | 30.0 | 149.1 | not |
| F010-H | 17 | 1645.203 | 60.000 | -35.032 | 0.0 | 67.8 | not |
| F010-S | 17 | 1644.143 | 60.000 | -38.201 | 0.0 | 80.1 | not |
| F011-H | 17 | 1644.783 | 60.000 | -41.402 | 0.0 | 43.2 | not |
| F011-S | 17 | 1645.151 | 60.000 | -34.521 | 0.0 | 50.4 | not |
| F012-H | 17 | 1644.980 | 60.000 | -32.235 | 0.0 | 83.4 | not |
| F012-S | 17 | 1644.061 | 60.000 | -31.110 | 0.0 | 92.7 | not |
| F013-H | 17 | 1644.501 | 60.000 | -37.652 | 0.0 | 90.6 | not |
| F013-S | 17 | 1644.181 | 60.000 | -26.681 | 0.0 | 133.2 | not |
| F014-H | 17 | 1644.385 | 60.000 | -36.103 | 0.0 | 74.1 | not |
| F014-S | 17 | 1644.972 | 60.000 | -33.096 | 0.0 | 51.6 | not |
| F015-H | 17 | 1644.457 | 60.000 | -28.244 | 0.0 | 75.6 | not |
| F015-S | 17 | 1644.973 | 60.000 | -27.284 | 0.0 | 86.4 | not |
| F016-H | 17 | 1645.119 | 60.000 | -27.820 | 90.0 | 33.6 | not |
| F016-S | 17 | 1645.200 | 60.000 | -35.072 | 90.0 | 22.2 | not |
| F017-H | 17 | 1644.756 | 60.000 | -53.924 | 57.0 | 42.6 | not |
| F017-S | 17 | 1644.892 | 60.000 | -39.303 | 0.0 | 59.7 | not |
| F018-H | 17 | 1644.747 | 60.000 | -36.331 | 36.0 | 35.1 | not |
| F018-S | 17 | 1644.504 | 60.000 | -39.307 | 0.0 | 54.0 | not |
| F019-H | 17 | 1644.635 | 60.000 | -38.762 | 0.0 | 57.3 | not |
| F019-S | 17 | 1643.869 | 60.000 | -30.065 | 0.0 | 109.5 | not |
| F020-H | 17 | 1644.632 | 60.000 | -33.118 | 0.0 | 78.3 | not |
| F020-S | 17 | 1644.864 | 60.000 | -28.612 | 0.0 | 71.1 | not |
| F021-H | 17 | 1645.080 | 60.000 | -31.387 | 0.0 | 84.3 | not |
| F021-S | 17 | 1643.927 | 60.000 | -26.968 | 0.0 | 93.6 | not |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| F022-H | 17 | 1644.402 | 60.000 | -143.031 | 0.0 | 83.7 | CATCH |
| F022-S | 17 | 1644.260 | 60.000 | -38.501 | 0.0 | 69.0 | not |
| F023-H | 17 | 1645.047 | 60.000 | -34.171 | 0.0 | 41.1 | not |
| F023-S | 17 | 1644.705 | 60.000 | -33.632 | 0.0 | 87.9 | not |
| F024-H | 17 | 1645.223 | 60.000 | -28.743 | 0.0 | 43.2 | not |
| F024-S | 17 | 1644.728 | 60.000 | -23.512 | 0.0 | 38.7 | not |
| F025-H | 17 | 1644.336 | 60.000 | -26.487 | 0.0 | 78.9 | not |
| F025-S | 17 | 1644.959 | 60.000 | -21.404 | 0.0 | 70.2 | not |
| F026-H | 17 | 1644.551 | 60.000 | -30.866 | 0.0 | 82.8 | not |
| F026-S | 17 | 1644.268 | 60.000 | -27.303 | 0.0 | 70.8 | not |
| F027-H | 17 | 1644.104 | 60.000 | -29.437 | 0.0 | 80.1 | not |
| F027-S | 17 | 1643.782 | 60.000 | -28.895 | 0.0 | 101.1 | not |
| F028-H | 17 | 1644.905 | 60.000 | -40.256 | 0.0 | 22.8 | not |
| F028-S | 17 | 1645.010 | 60.000 | -36.351 | 0.0 | 84.0 | not |
| F029-H | 17 | 1644.290 | 60.000 | -141.763 | 0.0 | 72.6 | CATCH |
| F029-S | 17 | 1645.028 | 60.000 | -25.171 | 0.0 | 40.8 | not |
| F030-H | 17 | 1644.148 | 60.000 | -30.975 | 0.0 | 72.3 | not |
| F030-S | 17 | 1644.655 | 60.000 | -37.117 | 0.0 | 75.6 | not |
| F031-H | 17 | 1645.109 | 60.000 | -34.291 | 0.0 | 51.6 | not |
| F031-S | 17 | 1644.849 | 60.000 | -30.866 | 0.0 | 40.5 | not |
| F032-H | 17 | 1645.195 | 60.000 | -39.424 | 0.0 | 111.0 | not |
| F032-S | 17 | 1644.097 | 60.000 | -35.997 | 0.0 | 94.5 | not |
| F033-H | 17 | 1645.070 | 60.000 | -26.591 | 0.0 | 86.7 | not |
| F033-S | 17 | 1644.437 | 60.000 | -33.917 | 0.0 | 119.7 | not |
| F034-H | 17 | 1644.598 | 60.000 | -30.546 | 0.0 | 124.5 | not |
| F034-S | 17 | 1643.704 | 60.000 | -29.443 | 0.0 | 117.9 | not |
| F035-H | 17 | 1645.067 | 60.000 | -25.067 | 90.0 | 55.5 | not |
| F035-S | 17 | 1645.076 | 60.000 | -29.402 | 0.0 | 43.2 | not |
| F036-H | 17 | 1644.853 | 60.000 | -18.737 | 0.0 | 33.3 | not |
| F036-S | 17 | 1645.176 | 60.000 | -37.686 | 0.0 | 22.2 | not |
| F037-H | 17 | 1644.833 | 60.000 | -40.599 | 0.0 | 53.1 | not |
| F037-S | 17 | 1643.955 | 60.000 | -27.250 | 0.0 | 94.5 | not |
| F038-H | 17 | 1644.583 | 60.000 | -41.616 | 0.0 | 64.5 | not |
| F038-S | 17 | 1644.956 | 60.000 | -30.840 | 0.0 | 69.3 | not |
| F040-H | 17 | 1645.181 | 60.000 | -38.618 | 0.0 | 51.6 | not |
| F040-S | 17 | 1644.989 | 60.000 | -26.601 | 0.0 | 51.0 | not |
| F041-H | 17 | 1645.147 | 60.000 | -142.363 | 0.0 | 16.8 | CATCH |
| F041-S | 17 | 1644.841 | 60.000 | -143.998 | 0.0 | 49.8 | CATCH |
| F042-H | 17 | 1644.718 | 60.000 | -30.812 | 0.0 | 46.2 | not |
| F042-S | 17 | 1644.474 | 60.000 | -28.622 | 0.0 | 51.3 | not |
| F043-H | 17 | 1644.990 | 60.000 | -25.327 | 0.0 | 20.7 | not |
| F043-S | 17 | 1644.655 | 60.000 | -31.105 | 0.0 | 50.1 | not |
| H001-H | 17 | 1644.852 | 60.000 | -27.992 | 0.0 | 77.7 | not |
| H002-H | 17 | 1645.152 | 60.000 | -48.646 | 0.0 | 34.5 | not |
| H003-H | 17 | 1644.983 | 60.000 | -38.535 | 0.0 | 71.1 | not |
| I001-H | 17 | 1644.955 | 60.000 | -37.540 | 0.0 | 91.8 | not |
| I001-S | 17 | 1644.413 | 60.000 | -30.541 | 0.0 | 88.8 | not |
| P001-H | 17 | 1644.236 | 60.000 | -31.278 | 0.0 | 67.8 | not |
| P001-S | 17 | 1645.219 | 60.000 | -28.271 | 0.0 | 68.7 | not |
| P002-H | 17 | 1644.230 | 60.000 | -32.319 | 0.0 | 67.2 | not |
| P002-S | 17 | 1644.620 | 60.000 | -39.294 | 0.0 | 68.4 | not |
| P003-H | 17 | 1645.198 | 60.000 | -43.123 | 0.0 | 15.0 | not |
| P003-S | 17 | 1645.107 | 60.000 | -15.385 | 0.0 | 33.6 | not |
| P004-H | 17 | 1644.820 | 60.000 | -31.329 | 0.0 | 61.2 | not |
| P004-S | 17 | 1644.679 | 60.000 | -18.714 | 0.0 | 44.1 | not |
| P005-H | 17 | 1645.068 | 60.000 | -34.284 | 90.0 | 13.2 | not |
| P005-S | 17 | 1645.249 | 60.000 | -30.162 | 90.0 | 31.8 | not |
| P006-H | 17 | 1644.383 | 60.000 | -15.179 | 0.0 | 87.9 | not |
| P006-S | 17 | 1645.016 | 60.000 | -15.155 | 0.0 | 60.9 | not |
| P007-H | 17 | 1644.853 | 60.000 | -46.890 | 90.0 | 28.8 | not |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| P007-S | 17 | 1644.773 | 60.000 | -23.589 | 0.0 | 33.6 | not |
| P008-H | 17 | 1644.970 | 60.000 | -39.291 | 0.0 | 58.2 | not |
| P008-S | 17 | 1644.923 | 60.000 | -34.238 | 0.0 | 91.8 | not |
| P009-H | 17 | 1644.029 | 60.000 | -40.044 | 0.0 | 132.6 | not |
| P009-S | 17 | 1642.896 | 60.000 | -30.595 | 0.0 | 139.5 | not |
| P010-H | 17 | 1644.016 | 60.000 | -128.275 | 0.0 | 85.8 | CATCH |
| P010-S | 17 | 1645.200 | 60.000 | -48.669 | 0.0 | 54.0 | not |

## Task Room 18 Reduced Data

| File | Room | X | Y | Z | Rotate | Speed | RESULT |
|---|---|---|---|---|---|---|---|
| A001-H | 18 | 1811.478 | 60.000 | -564.204 | 90.0 | 61.8 | m/b |
| A002-H | 18 | 1719.157 | 60.000 | -563.307 | 0.0 | 87.9 | no |
| A003-H | 18 | 1816.408 | 125.000 | -564.118 | 0.0 | 54.6 | FLY |
| A004-H | 18 | 1810.821 | 121.000 | -564.179 | 0.0 | 91.5 | FLY |
| A005-H | 18 | 1812.511 | 125.000 | -564.214 | 0.0 | 53.7 | FLY |
| B001-H | 18 | 1821.798 | 60.000 | -564.415 | 0.0 | 12.0 | no |
| B001-S | 18 | 1712.299 | 60.000 | -564.405 | 0.0 | 29.4 | no |
| B002-H | 18 | 1814.921 | 125.000 | -564.177 | 0.0 | 59.4 | FLY |
| B002-S | 18 | 1722.511 | 60.000 | -564.336 | 33.0 | 70.5 | m/b |
| B003-H | 18 | 1803.665 | 88.000 | -563.692 | 0.0 | 52.8 | FLY |
| B003-S | 18 | 1715.907 | 60.000 | -563.579 | 0.0 | 60.6 | no |
| B004-H | 18 | 1711.565 | 60.000 | -564.193 | 0.0 | 61.8 | no |
| B004-S | 18 | 1719.813 | 60.000 | -564.450 | 0.0 | 87.0 | no |
| B005-H | 18 | 1719.392 | 60.000 | -564.021 | 0.0 | 33.3 | no |
| B005-S | 18 | 1727.699 | 60.000 | -564.114 | 0.0 | 42.3 | no |
| F001-H | 18 | 1819.542 | 111.000 | -564.421 | 0.0 | 39.3 | FLY |
| F001-S | 18 | 1848.031 | 125.000 | -563.912 | 0.0 | 43.2 | FLY |
| F002-H | 18 | 1794.222 | 125.000 | -564.349 | 0.0 | 88.2 | FLY |
| F002-S | 18 | 1803.269 | 99.000 | -564.150 | 0.0 | 62.1 | FLY |
| F003-H | 18 | 1801.067 | 125.000 | -563.374 | 0.0 | 90.0 | FLY |
| F003-S | 18 | 1804.303 | 125.000 | -563.269 | 0.0 | 95.1 | FLY |
| F004-H | 18 | 1731.622 | 60.000 | -563.374 | 0.0 | 86.4 | no |
| F004-S | 18 | 1726.547 | 60.000 | -563.635 | 0.0 | 78.6 | no |
| F005-H | 18 | 1813.195 | 125.000 | -563.073 | 0.0 | 150.0 | FLY |
| F005-S | 18 | 1817.549 | 125.000 | -562.458 | 0.0 | 127.5 | FLY |
| F006-H | 18 | 1806.490 | 119.000 | -563.482 | 0.0 | 135.9 | FLY |
| F006-S | 18 | 1720.395 | 60.000 | -563.835 | 0.0 | 74.4 | no |
| F007-H | 18 | 1804.343 | 125.000 | -564.127 | 0.0 | 37.8 | FLY |
| F007-S | 18 | 1716.028 | 60.000 | -564.400 | 0.0 | 51.6 | no |
| F008-H | 18 | 1812.440 | 125.000 | -564.403 | 0.0 | 57.3 | FLY |
| F008-S | 18 | 1811.932 | 125.000 | -563.862 | 0.0 | 54.0 | FLY |
| F009-H | 18 | 1816.198 | 115.000 | -564.184 | 0.0 | 82.2 | FLY |
| F009-S | 18 | 1818.907 | 125.000 | -563.197 | 0.0 | 150.0 | FLY |
| F010-H | 18 | 1815.771 | 105.000 | -564.092 | 0.0 | 66.6 | FLY |
| F010-S | 18 | 1724.051 | 60.000 | -564.198 | 0.0 | 67.8 | no |
| F011-H | 18 | 1800.160 | 125.000 | -563.951 | 0.0 | 33.3 | FLY |
| F011-S | 18 | 1719.710 | 60.000 | -564.246 | 0.0 | 48.6 | no |
| F012-H | 18 | 1727.439 | 60.000 | -564.014 | 0.0 | 65.4 | no |
| F012-S | 18 | 1713.558 | 60.000 | -563.565 | 0.0 | 94.5 | no |
| F013-H | 18 | 1835.381 | 125.000 | -563.571 | 0.0 | 96.3 | FLY |
| F013-S | 18 | 1726.184 | 60.000 | -564.352 | 0.0 | 140.4 | no |
| F014-H | 18 | 1807.353 | 125.000 | -564.225 | 0.0 | 68.7 | FLY |
| F014-S | 18 | 1812.412 | 125.000 | -564.056 | 0.0 | 76.2 | FLY |
| F015-H | 18 | 1807.102 | 125.000 | -563.666 | 0.0 | 81.9 | FLY |
| F015-S | 18 | 1717.559 | 60.000 | -563.009 | 0.0 | 121.8 | no |
| F016-H | 18 | 1811.586 | 125.000 | -564.219 | 0.0 | 45.3 | FLY |
| F016-S | 18 | 1820.588 | 125.000 | -563.963 | 0.0 | 51.9 | FLY |
| F017-H | 18 | 1822.019 | 113.000 | -564.454 | 0.0 | 75.9 | FLY |
| F017-S | 18 | 1820.138 | 111.000 | -563.288 | 0.0 | 79.8 | FLY |

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|---|---|---|---|---|---|---|---|
| F018-H | 18 | 1805.453 | 95.000 | -564.028 | 0.0 | 64.8 | FLY |
| F018-S | 18 | 1820.957 | 125.000 | -564.183 | 0.0 | 45.9 | FLY |
| F019-H | 18 | 1718.427 | 60.000 | -563.443 | 90.0 | 67.8 | m/b |
| F019-S | 18 | 1829.740 | 125.000 | -562.935 | 0.0 | 117.3 | FLY |
| F020-H | 18 | 1712.891 | 60.000 | -564.413 | 0.0 | 74.7 | no |
| F020-S | 18 | 1798.792 | 125.000 | -564.305 | 0.0 | 81.3 | FLY |
| F021-H | 18 | 1821.224 | 125.000 | -563.448 | 0.0 | 87.9 | FLY |
| F021-S | 18 | 1724.750 | 60.000 | -563.526 | 0.0 | 78.6 | no |
| F022-H | 18 | 1713.531 | 60.000 | -563.166 | 0.0 | 104.4 | no |
| F022-S | 18 | 1716.619 | 60.000 | -563.941 | 60.0 | 80.7 | m/b |
| F023-H | 18 | 1814.101 | 119.000 | -564.002 | 0.0 | 66.9 | FLY |
| F023-S | 18 | 1722.598 | 60.000 | -563.290 | 0.0 | 99.9 | no |
| F024-H | 18 | 1821.702 | 83.000 | -564.417 | 0.0 | 47.7 | FLY |
| F024-S | 18 | 1714.809 | 60.000 | -564.274 | 0.0 | 36.9 | no |
| F025-H | 18 | 1724.717 | 60.000 | -564.044 | 0.0 | 80.7 | no |
| F025-S | 18 | 1721.003 | 60.000 | -563.823 | 0.0 | 78.9 | no |
| F026-H | 18 | 1716.081 | 60.000 | -563.497 | 0.0 | 78.3 | no |
| F026-S | 18 | 1713.650 | 60.000 | -564.434 | 0.0 | 69.6 | no |
| F027-H | 18 | 1808.123 | 125.000 | -564.078 | 0.0 | 58.5 | FLY |
| F027-S | 18 | 1720.782 | 60.000 | -563.451 | 0.0 | 73.2 | no |
| F028-H | 18 | 1717.228 | 60.000 | -564.134 | 90.0 | 65.1 | m/b |
| F028-S | 18 | 1726.137 | 60.000 | -563.973 | 90.0 | 115.8 | m/b |
| F029-H | 18 | 1805.843 | 79.000 | -564.201 | 0.0 | 72.3 | FLY |
| F029-S | 18 | 1711.082 | 60.000 | -563.515 | 0.0 | 63.9 | no |
| F030-H | 18 | 1716.683 | 60.000 | -563.634 | 0.0 | 76.5 | no |
| F030-S | 18 | 1720.610 | 60.000 | -563.980 | 0.0 | 55.5 | no |
| F031-H | 18 | 1817.762 | 60.000 | -564.425 | 0.0 | 42.3 | no |
| F031-S | 18 | 1717.159 | 60.000 | -564.436 | 0.0 | 77.7 | no |
| F032-H | 18 | 1802.806 | 60.000 | -564.153 | 0.0 | 57.6 | no |
| F032-S | 18 | 1714.234 | 60.000 | -564.363 | 0.0 | 103.2 | no |
| F033-H | 18 | 1837.149 | 125.000 | -563.207 | 0.0 | 121.5 | FLY |
| F033-S | 18 | 1721.156 | 60.000 | -564.000 | 0.0 | 129.9 | no |
| F034-H | 18 | 1715.971 | 60.000 | -564.357 | 0.0 | 132.9 | no |
| F034-S | 18 | 1716.401 | 60.000 | -562.769 | 0.0 | 115.2 | no |
| F035-H | 18 | 1720.734 | 60.000 | -563.917 | 90.0 | 45.0 | m/b |
| F035-S | 18 | 1723.933 | 60.000 | -564.436 | 90.0 | 45.0 | m/b |
| F036-H | 18 | 1821.950 | 60.000 | -564.455 | 0.0 | 31.2 | no |
| F036-S | 18 | 1714.108 | 60.000 | -564.303 | 0.0 | 31.5 | no |
| F037-H | 18 | 1809.728 | 103.000 | -562.797 | 0.0 | 103.2 | FLY |
| F037-S | 18 | 1715.601 | 60.000 | -563.843 | 0.0 | 117.0 | no |
| F038-H | 18 | 1820.393 | 60.000 | -563.958 | 0.0 | 67.8 | no |
| F038-S | 18 | 1732.399 | 60.000 | -564.436 | 0.0 | 70.8 | no |
| F040-H | 18 | 1713.213 | 60.000 | -564.040 | 0.0 | 60.9 | no |
| F040-S | 18 | 1719.525 | 60.000 | -564.037 | 0.0 | 57.9 | no |
| F041-H | 18 | 1718.990 | 60.000 | -564.036 | 0.0 | 46.2 | no |
| F041-S | 18 | 1718.575 | 60.000 | -564.051 | 0.0 | 67.5 | no |
| F042-H | 18 | 1703.351 | 60.000 | -564.476 | 0.0 | 50.7 | no |
| F042-S | 18 | 1722.897 | 60.000 | -563.759 | 0.0 | 57.6 | no |
| F043-H | 18 | 1824.325 | 125.000 | -564.371 | 0.0 | 57.3 | FLY |
| F043-S | 18 | 1723.793 | 60.000 | -564.096 | 0.0 | 39.6 | no |
| H001-H | 18 | 1722.127 | 60.000 | -563.892 | 0.0 | 72.9 | no |
| H002-H | 18 | 1818.128 | 109.000 | -564.375 | 0.0 | 55.8 | FLY |
| H003-H | 18 | 1830.432 | 125.000 | -564.354 | 0.0 | 91.5 | FLY |
| I001-H | 18 | 1818.098 | 95.000 | -564.067 | 0.0 | 100.8 | FLY |
| I001-S | 18 | 1715.111 | 60.000 | -563.491 | 0.0 | 86.1 | no |
| P001-H | 18 | 1805.214 | 60.000 | -564.474 | 0.0 | 69.3 | no |
| P001-S | 18 | 1716.215 | 60.000 | -563.652 | 90.0 | 83.4 | m/b |
| P002-H | 18 | 1831.277 | 102.000 | -563.681 | 0.0 | 68.4 | FLY |
| P002-S | 18 | 1721.189 | 60.000 | -564.365 | 0.0 | 78.9 | no |
| P003-H | 18 | 1720.260 | 60.000 | -564.186 | 0.0 | 20.1 | no |

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|---|---|---|---|---|---|---|---|
| P003-S | 18 | 1726.145 | 60.000 | -564.269 | 0.0 | 22.8 | no |
| P004-H | 18 | 1822.676 | 178.000 | -564.382 | 0.0 | 73.5 | FLY |
| P004-S | 18 | 1824.835 | 114.000 | -564.144 | 0.0 | 47.4 | FLY |
| P005-H | 18 | 1821.990 | 64.000 | -564.054 | 0.0 | 36.3 | FLY |
| P005-S | 18 | 1822.507 | 176.000 | -563.778 | 0.0 | 70.8 | FLY |
| P006-H | 18 | 1718.519 | 60.000 | -563.799 | 0.0 | 81.9 | no |
| P006-S | 18 | 1834.389 | 126.000 | -564.157 | 0.0 | 56.7 | FLY |
| P007-H | 18 | 1721.718 | 60.000 | -564.481 | 90.0 | 31.2 | m/b |
| P007-S | 18 | 1815.735 | 238.000 | -564.479 | 0.0 | 42.6 | FLY |
| P008-H | 18 | 1727.620 | 60.000 | -563.437 | 0.0 | 84.9 | no |
| P008-S | 18 | 1725.527 | 60.000 | -564.308 | 0.0 | 120.9 | no |
| P009-H | 18 | 1804.290 | 128.000 | -563.917 | 0.0 | 92.4 | FLY |
| P009-S | 18 | 1819.289 | 174.000 | -564.091 | 0.0 | 137.4 | FLY |
| P010-H | 18 | 1736.918 | 60.000 | -563.954 | 0.0 | 67.2 | no |
| P010-S | 18 | 1726.248 | 60.000 | -564.445 | 0.0 | 61.5 | no |

## Task Room 19 Reduced Data

| File | Room | X | Y | Z | Rotate | Speed | RESULT |
|---|---|---|---|---|---|---|---|
| A001-H | 19 | 2234.310 | 60.000 | -674.933 | 0.0 | 57.3 | no |
| A002-H | 19 | 2233.182 | 60.000 | -671.119 | 0.0 | 101.4 | no |
| A003-H | 19 | 2234.503 | 60.000 | -669.012 | 0.0 | 45.0 | no |
| A004-H | 19 | 2233.936 | 60.000 | -673.617 | 0.0 | 70.8 | no |
| A005-H | 19 | 2234.464 | 60.000 | -671.617 | 0.0 | 70.2 | no |
| B001-H | 19 | 2234.739 | 60.000 | -693.128 | 0.0 | 13.8 | no |
| B001-S | 19 | 2234.471 | 60.000 | -687.853 | 90.0 | 36.3 | ROTATE |
| B002-H | 19 | 2233.956 | 60.000 | -693.485 | 87.0 | 57.0 | ROTATE |
| B002-S | 19 | 2233.797 | 60.000 | -683.448 | 90.0 | 78.3 | ROTATE |
| B003-H | 19 | 2234.345 | 60.000 | -692.341 | 0.0 | 46.8 | no |
| B003-S | 19 | 2233.854 | 60.000 | -689.350 | 0.0 | 80.1 | no |
| B004-H | 19 | 2234.474 | 60.000 | -693.398 | 0.0 | 54.3 | no |
| B004-S | 19 | 2233.377 | 60.000 | -690.714 | 90.0 | 81.6 | ROTATE |
| B005-H | 19 | 2234.471 | 60.000 | -699.480 | 0.0 | 24.6 | no |
| B005-S | 19 | 2234.442 | 60.000 | -691.106 | 0.0 | 47.7 | no |
| F001-H | 19 | 2234.728 | 60.000 | -687.600 | 90.0 | 50.1 | ROTATE |
| F001-S | 19 | 2233.984 | 60.000 | -685.315 | 90.0 | 62.4 | ROTATE |
| F002-H | 19 | 2234.594 | 60.000 | -689.404 | 90.0 | 105.6 | ROTATE |
| F002-S | 19 | 2234.673 | 60.000 | -694.429 | 6.0 | 62.1 | no |
| F003-H | 19 | 2233.975 | 60.000 | -691.813 | 90.0 | 92.7 | ROTATE |
| F003-S | 19 | 2233.175 | 60.000 | -691.206 | 90.0 | 105.9 | ROTATE |
| F004-H | 19 | 2233.580 | 60.000 | -691.079 | 0.0 | 86.1 | no |
| F004-S | 19 | 2234.369 | 60.000 | -689.411 | 0.0 | 100.8 | no |
| F005-H | 19 | 2234.587 | 60.000 | -687.780 | 90.0 | 73.8 | ROTATE |
| F005-S | 19 | 2233.749 | 60.000 | -687.618 | 90.0 | 112.5 | ROTATE |
| F006-H | 19 | 2233.802 | 60.000 | -686.631 | 90.0 | 142.2 | ROTATE |
| F006-S | 19 | 2233.664 | 60.000 | -687.683 | 66.0 | 76.5 | ROTATE |
| F007-H | 19 | 2234.674 | 60.000 | -686.551 | 90.0 | 72.9 | ROTATE |
| F007-S | 19 | 2234.636 | 60.000 | -689.254 | 90.0 | 67.2 | ROTATE |
| F008-H | 19 | 2234.012 | 60.000 | -688.607 | 90.0 | 51.3 | ROTATE |
| F008-S | 19 | 2233.884 | 60.000 | -690.063 | 90.0 | 60.0 | ROTATE |
| F009-H | 19 | 2234.425 | 60.000 | -689.149 | 90.0 | 84.3 | ROTATE |
| F009-S | 19 | 2233.594 | 60.000 | -689.772 | 81.0 | 150.0 | ROTATE |
| F010-H | 19 | 2234.105 | 60.000 | -690.719 | 90.0 | 60.0 | ROTATE |
| F010-S | 19 | 2233.488 | 60.000 | -688.059 | 24.0 | 98.1 | ROTATE |
| F011-H | 19 | 2234.679 | 60.000 | -690.708 | 90.0 | 33.3 | ROTATE |
| F011-S | 19 | 2234.341 | 60.000 | -688.793 | 90.0 | 44.1 | ROTATE |
| F012-H | 19 | 2234.744 | 60.000 | -687.239 | 0.0 | 81.9 | no |
| F012-S | 19 | 2233.257 | 60.000 | -685.900 | 0.0 | 97.2 | no |
| F013-H | 19 | 2233.723 | 60.000 | -686.912 | 90.0 | 83.7 | ROTATE |
| F013-S | 19 | 2234.068 | 60.000 | -686.588 | 0.0 | 144.3 | no |

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|---|---|---|---|---|---|---|---|
| F014-H | 19 | 2234.676 | 60.000 | -689.783 | 0.0 | 62.4 | no |
| F014-S | 19 | 2233.905 | 60.000 | -689.410 | 0.0 | 60.3 | no |
| F015-H | 19 | 2234.150 | 60.000 | -688.699 | 90.0 | 78.6 | ROTATE |
| F015-S | 19 | 2232.821 | 60.000 | -687.317 | 90.0 | 122.4 | ROTATE |
| F016-H | 19 | 2234.192 | 60.000 | -688.697 | 90.0 | 36.3 | ROTATE |
| F016-S | 19 | 2234.509 | 60.000 | -687.217 | 90.0 | 45.6 | ROTATE |
| F017-H | 19 | 2234.139 | 60.000 | -692.518 | 90.0 | 48.3 | ROTATE |
| F017-S | 19 | 2234.305 | 60.000 | -691.002 | 75.0 | 66.9 | ROTATE |
| F018-H | 19 | 2234.128 | 60.000 | -690.361 | 90.0 | 51.0 | ROTATE |
| F018-S | 19 | 2234.149 | 60.000 | -688.124 | 90.0 | 51.0 | ROTATE |
| F019-H | 19 | 2234.163 | 60.000 | -686.521 | 90.0 | 93.6 | ROTATE |
| F019-S | 19 | 2234.708 | 60.000 | -683.620 | 66.0 | 77.7 | ROTATE |
| F020-H | 19 | 2234.487 | 60.000 | -689.787 | 90.0 | 81.3 | ROTATE |
| F020-S | 19 | 2233.698 | 60.000 | -688.106 | 90.0 | 82.8 | ROTATE |
| F021-H | 19 | 2233.965 | 60.000 | -688.767 | 0.0 | 86.4 | no |
| F021-S | 19 | 2234.014 | 60.000 | -688.640 | 0.0 | 90.3 | no |
| F022-H | 19 | 2233.547 | 60.000 | -691.607 | 51.0 | 110.4 | ROTATE |
| F022-S | 19 | 2234.055 | 60.000 | -692.665 | 90.0 | 84.9 | ROTATE |
| F023-H | 19 | 2234.352 | 60.000 | -692.326 | 9.0 | 57.3 | no |
| F023-S | 19 | 2233.592 | 96.000 | -689.370 | 0.0 | 100.5 | m/b |
| F024-H | 19 | 2234.365 | 60.000 | -690.083 | 93.0 | 55.8 | ROTATE |
| F024-S | 19 | 2234.097 | 60.000 | -687.092 | 90.0 | 54.0 | ROTATE |
| F025-H | 19 | 2233.776 | 60.000 | -685.798 | 75.0 | 65.1 | ROTATE |
| F025-S | 19 | 2234.064 | 60.000 | -688.703 | 57.0 | 73.5 | ROTATE |
| F026-H | 19 | 2233.309 | 60.000 | -687.112 | 90.0 | 91.2 | ROTATE |
| F026-S | 19 | 2234.743 | 60.000 | -688.799 | 90.0 | 91.5 | ROTATE |
| F027-H | 19 | 2234.422 | 60.000 | -690.713 | 90.0 | 46.8 | ROTATE |
| F027-S | 19 | 2233.995 | 60.000 | -688.016 | 0.0 | 112.8 | no |
| F028-H | 19 | 2234.022 | 60.000 | -685.636 | 90.0 | 89.4 | ROTATE |
| F028-S | 19 | 2233.514 | 60.000 | -686.244 | 69.0 | 113.4 | ROTATE |
| F029-H | 19 | 2233.806 | 60.000 | -690.843 | 90.0 | 78.6 | ROTATE |
| F029-S | 19 | 2234.515 | 60.000 | -690.103 | 90.0 | 59.4 | ROTATE |
| F030-H | 19 | 2234.385 | 60.000 | -686.706 | 90.0 | 60.6 | ROTATE |
| F030-S | 19 | 2233.923 | 60.000 | -687.878 | 90.0 | 52.8 | ROTATE |
| F031-H | 19 | 2234.037 | 60.000 | -690.111 | 54.0 | 45.9 | ROTATE |
| F031-S | 19 | 2233.709 | 60.000 | -689.862 | 90.0 | 73.8 | ROTATE |
| F032-H | 19 | 2233.994 | 60.000 | -687.663 | 90.0 | 96.9 | ROTATE |
| F032-S | 19 | 2233.172 | 60.000 | -687.836 | 90.0 | 113.4 | ROTATE |
| F033-H | 19 | 2233.467 | 60.000 | -692.524 | 90.0 | 95.7 | ROTATE |
| F033-S | 19 | 2234.475 | 60.000 | -688.598 | 0.0 | 146.1 | no |
| F034-H | 19 | 2234.692 | 60.000 | -690.558 | 81.0 | 139.5 | ROTATE |
| F034-S | 19 | 2233.400 | 60.000 | -691.080 | 90.0 | 116.7 | ROTATE |
| F035-H | 19 | 2234.076 | 60.000 | -690.520 | 90.0 | 56.4 | ROTATE |
| F035-S | 19 | 2234.254 | 60.000 | -690.281 | 90.0 | 48.6 | ROTATE |
| F036-H | 19 | 2234.440 | 60.000 | -688.787 | 90.0 | 39.0 | ROTATE |
| F036-S | 19 | 2234.419 | 60.000 | -689.919 | 45.0 | 23.7 | ROTATE |
| F037-H | 19 | 2234.374 | 60.000 | -691.268 | 90.0 | 67.5 | ROTATE |
| F037-S | 19 | 2234.004 | 60.000 | -685.104 | 90.0 | 131.4 | ROTATE |
| F038-H | 19 | 2233.689 | 60.000 | -696.089 | 90.0 | 63.9 | ROTATE |
| F038-S | 19 | 2234.586 | 60.000 | -701.520 | 90.0 | 65.1 | ROTATE |
| F040-H | 19 | 2233.927 | 60.000 | -689.766 | 0.0 | 56.7 | no |
| F040-S | 19 | 2234.556 | 60.000 | -688.036 | 0.0 | 49.2 | no |
| F041-H | 19 | 2234.260 | 60.000 | -689.393 | 0.0 | 31.2 | no |
| F041-S | 19 | 2234.244 | 60.000 | -686.877 | 90.0 | 70.8 | ROTATE |
| F042-H | 19 | 2234.644 | 60.000 | -696.318 | 90.0 | 45.6 | ROTATE |
| F042-S | 19 | 2234.495 | 60.000 | -688.807 | 0.0 | 44.7 | no |
| F043-H | 19 | 2234.153 | 60.000 | -687.535 | 0.0 | 59.4 | no |
| F043-S | 19 | 2234.493 | 60.000 | -689.652 | 90.0 | 49.5 | ROTATE |
| H001-H | 19 | 2234.025 | 60.000 | -689.289 | 90.0 | 53.4 | ROTATE |
| H002-H | 19 | 2234.146 | 60.000 | -698.621 | 0.0 | 43.2 | no |

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|---|---|---|---|---|---|---|---|
| H003-H | 19 | 2233.313 | 60.000 | -692.588 | 90.0 | 87.9 | ROTATE |
| I001-H | 19 | 2233.416 | 60.000 | -690.445 | 0.0 | 100.8 | no |
| I001-S | 19 | 2233.275 | 60.000 | -695.166 | 90.0 | 96.6 | ROTATE |
| P001-H | 19 | 2234.458 | 60.000 | -688.923 | 90.0 | 77.1 | ROTATE |
| P001-S | 19 | 2234.536 | 60.000 | -687.478 | 90.0 | 79.5 | ROTATE |
| P002-H | 19 | 2233.967 | 60.000 | -689.631 | 90.0 | 72.9 | ROTATE |
| P002-S | 19 | 2233.854 | 60.000 | -692.237 | 78.0 | 82.5 | ROTATE |
| P003-H | 19 | 2234.537 | 60.000 | -693.519 | 0.0 | 23.7 | no |
| P003-S | 19 | 2234.426 | 60.000 | -690.843 | 63.0 | 33.0 | ROTATE |
| P004-H | 19 | 2234.101 | 192.000 | -691.983 | 0.0 | 80.1 | m/b |
| P004-S | 19 | 2234.521 | 60.000 | -688.625 | 87.0 | 34.2 | ROTATE |
| P005-H | 19 | 2234.395 | 60.000 | -689.487 | 90.0 | 41.4 | ROTATE |
| P005-S | 19 | 2234.387 | 60.000 | -688.654 | 90.0 | 38.1 | ROTATE |
| P006-H | 19 | 2234.137 | 60.000 | -689.526 | 0.0 | 61.8 | no |
| P006-S | 19 | 2234.346 | 60.000 | -688.211 | 0.0 | 62.7 | no |
| P007-H | 19 | 2234.206 | 60.000 | -689.122 | 90.0 | 53.4 | ROTATE |
| P007-S | 19 | 2234.712 | 60.000 | -687.782 | 90.0 | 45.6 | ROTATE |
| P008-H | 19 | 2233.854 | 60.000 | -685.696 | 0.0 | 77.1 | no |
| P008-S | 19 | 2234.196 | 60.000 | -694.212 | 0.0 | 140.1 | no |
| P009-H | 19 | 2233.756 | 60.000 | -687.525 | 0.0 | 129.6 | no |
| P009-S | 19 | 2232.937 | 60.000 | -690.846 | 0.0 | 130.8 | no |
| P010-H | 19 | 2234.064 | 60.000 | -690.353 | 90.0 | 57.0 | ROTATE |
| P010-S | 19 | 2233.808 | 60.000 | -687.157 | 0.0 | 63.0 | no |

## Task Room 20 Reduced Data

| File | Room | X | Y | Z | Rotate | Speed | RESULT |
|---|---|---|---|---|---|---|---|
| A001-H | 20 | 2300.968 | 60.000 | -221.677 | 0.0 | 46.5 | not |
| A002-H | 20 | 2306.853 | 60.000 | -221.844 | 0.0 | 81.0 | not |
| A003-H | 20 | 2299.789 | 60.000 | -221.876 | 0.0 | 45.6 | not |
| A004-H | 20 | 2306.714 | 60.000 | -222.310 | 0.0 | 67.2 | not |
| A005-H | 20 | 2313.270 | 60.000 | -221.990 | 0.0 | 51.0 | not |
| B001-H | 20 | 2414.520 | 60.000 | -221.656 | 0.0 | 18.3 | CATCH |
| B001-S | 20 | 2307.806 | 60.000 | -222.067 | 0.0 | 38.1 | not |
| B002-H | 20 | 2408.704 | 60.000 | -221.938 | 0.0 | 55.8 | CATCH |
| B002-S | 20 | 2299.898 | 60.000 | -222.113 | 0.0 | 106.2 | not |
| B003-H | 20 | 2428.827 | 60.000 | -222.436 | 0.0 | 69.3 | CATCH |
| B003-S | 20 | 2299.192 | 60.000 | -222.293 | 0.0 | 92.1 | not |
| B004-H | 20 | 2425.318 | 60.000 | -221.738 | 0.0 | 47.7 | CATCH |
| B004-S | 20 | 2313.886 | 60.000 | -222.015 | 0.0 | 89.7 | not |
| B005-H | 20 | 2352.154 | 60.000 | -221.762 | 0.0 | 44.4 | not |
| B005-S | 20 | 2313.809 | 60.000 | -221.678 | 0.0 | 36.3 | not |
| F001-H | 20 | 2301.917 | 60.000 | -221.535 | 0.0 | 46.2 | not |
| F001-S | 20 | 2303.623 | 60.000 | -221.958 | 0.0 | 89.7 | not |
| F002-H | 20 | 2365.694 | 60.000 | -221.982 | 0.0 | 50.4 | CATCH |
| F002-S | 20 | 2311.994 | 60.000 | -222.076 | 0.0 | 74.7 | not |
| F003-H | 20 | 2425.004 | 60.000 | -222.314 | 0.0 | 82.5 | CATCH |
| F003-S | 20 | 2407.336 | 60.000 | -223.026 | 0.0 | 135.3 | CATCH |
| F004-H | 20 | 2318.179 | 60.000 | -222.630 | 0.0 | 91.8 | not |
| F004-S | 20 | 2318.113 | 60.000 | -221.632 | 0.0 | 72.9 | not |
| F005-H | 20 | 2413.233 | 60.000 | -222.768 | 0.0 | 119.7 | CATCH |
| F005-S | 20 | 2408.969 | 60.000 | -222.881 | 0.0 | 118.5 | CATCH |
| F006-H | 20 | 2427.831 | 60.000 | -223.602 | 0.0 | 140.1 | CATCH |
| F006-S | 20 | 2303.935 | 60.000 | -221.532 | 0.0 | 94.8 | not |
| F007-H | 20 | 2305.809 | 60.000 | -221.762 | 90.0 | 87.0 | not |
| F007-S | 20 | 2305.997 | 60.000 | -221.794 | 0.0 | 84.9 | not |
| F008-H | 20 | 2302.260 | 60.000 | -221.762 | 0.0 | 53.4 | not |
| F008-S | 20 | 2304.300 | 60.000 | -221.965 | 0.0 | 41.1 | not |
| F009-H | 20 | 2318.638 | 60.000 | -221.704 | 6.0 | 99.0 | not |
| F009-S | 20 | 2418.418 | 60.000 | -221.987 | 24.0 | 148.8 | CATCH |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| F010-H | 20 | 2308.727 | 60.000 | -222.045 | 0.0 | 83.1 | not |
| F010-S | 20 | 2425.194 | 60.000 | -221.522 | 0.0 | 118.2 | CATCH |
| F011-H | 20 | 2304.357 | 60.000 | -221.945 | 0.0 | 47.7 | not |
| F011-S | 20 | 2304.115 | 60.000 | -222.232 | 0.0 | 67.5 | not |
| F012-H | 20 | 2310.541 | 60.000 | -222.443 | 0.0 | 87.3 | not |
| F012-S | 20 | 2298.488 | 60.000 | -222.745 | 0.0 | 103.8 | not |
| F013-H | 20 | 2326.435 | 60.000 | -222.346 | 0.0 | 96.3 | not |
| F013-S | 20 | 2405.683 | 60.000 | -221.585 | 0.0 | 136.5 | CATCH |
| F014-H | 20 | 2306.454 | 60.000 | -222.676 | 0.0 | 78.9 | not |
| F014-S | 20 | 2311.726 | 60.000 | -221.769 | 0.0 | 78.0 | not |
| F015-H | 20 | 2307.184 | 60.000 | -221.836 | 0.0 | 76.5 | not |
| F015-S | 20 | 2308.289 | 60.000 | -222.391 | 0.0 | 116.7 | not |
| F016-H | 20 | 2305.317 | 60.000 | -221.626 | 90.0 | 25.5 | not |
| F016-S | 20 | 2308.413 | 60.000 | -222.006 | 90.0 | 58.5 | not |
| F017-H | 20 | 2321.588 | 60.000 | -221.837 | 0.0 | 49.5 | not |
| F017-S | 20 | 2331.574 | 60.000 | -221.839 | 0.0 | 51.6 | not |
| F018-H | 20 | 2411.472 | 60.000 | -221.573 | 0.0 | 44.4 | CATCH |
| F018-S | 20 | 2312.046 | 60.000 | -222.302 | 0.0 | 59.1 | not |
| F019-H | 20 | 2309.477 | 60.000 | -221.686 | 0.0 | 51.3 | not |
| F019-S | 20 | 2312.967 | 60.000 | -221.900 | 0.0 | 102.0 | not |
| F020-H | 20 | 2412.358 | 60.000 | -221.848 | 0.0 | 83.7 | CATCH |
| F020-S | 20 | 2305.219 | 60.000 | -222.973 | 0.0 | 105.0 | not |
| F021-H | 20 | 2305.868 | 60.000 | -222.542 | 0.0 | 81.3 | not |
| F021-S | 20 | 2308.239 | 60.000 | -222.399 | 0.0 | 90.3 | not |
| F022-H | 20 | 2410.846 | 60.000 | -222.174 | 0.0 | 77.1 | CATCH |
| F022-S | 20 | 2420.287 | 60.000 | -222.191 | 0.0 | 67.8 | CATCH |
| F023-H | 20 | 2417.826 | 60.000 | -221.777 | 0.0 | 40.8 | CATCH |
| F023-S | 20 | 2327.257 | 60.000 | -222.699 | 0.0 | 86.1 | not |
| F024-H | 20 | 2312.825 | 60.000 | -221.919 | 90.0 | 58.5 | not |
| F024-S | 20 | 2413.963 | 60.000 | -222.256 | 0.0 | 66.6 | CATCH |
| F025-H | 20 | 2300.079 | 60.000 | -222.110 | 0.0 | 81.9 | not |
| F025-S | 20 | 2299.129 | 60.000 | -222.430 | 0.0 | 70.8 | not |
| F026-H | 20 | 2306.633 | 60.000 | -221.992 | 0.0 | 78.3 | not |
| F026-S | 20 | 2308.377 | 60.000 | -221.668 | 0.0 | 82.5 | not |
| F027-H | 20 | 2307.906 | 60.000 | -221.928 | 0.0 | 87.9 | not |
| F027-S | 20 | 2305.931 | 60.000 | -221.693 | 0.0 | 109.5 | not |
| F028-H | 20 | 2418.734 | 60.000 | -221.697 | 0.0 | 77.7 | CATCH |
| F028-S | 20 | 2306.904 | 60.000 | -222.566 | 0.0 | 127.8 | not |
| F029-H | 20 | 2416.388 | 60.000 | -222.616 | 0.0 | 76.8 | CATCH |
| F029-S | 20 | 2302.468 | 60.000 | -221.798 | 0.0 | 48.3 | not |
| F030-H | 20 | 2307.359 | 60.000 | -222.607 | 0.0 | 75.6 | not |
| F030-S | 20 | 2301.653 | 60.000 | -221.567 | 0.0 | 62.1 | not |
| F031-H | 20 | 2313.756 | 60.000 | -221.856 | 0.0 | 57.9 | not |
| F031-S | 20 | 2309.525 | 60.000 | -222.179 | 0.0 | 69.3 | not |
| F032-H | 20 | 2312.227 | 60.000 | -222.810 | 0.0 | 106.8 | not |
| F032-S | 20 | 2310.200 | 60.000 | -222.931 | 0.0 | 112.8 | not |
| F033-H | 20 | 2315.791 | 60.000 | -222.734 | 0.0 | 89.1 | not |
| F033-S | 20 | 2304.862 | 60.000 | -221.717 | 0.0 | 147.6 | not |
| F034-H | 20 | 2298.858 | 60.000 | -222.079 | 0.0 | 146.7 | not |
| F034-S | 20 | 2307.215 | 60.000 | -222.757 | 0.0 | 123.0 | not |
| F035-H | 20 | 2303.933 | 60.000 | -221.696 | 90.0 | 55.2 | not |
| F035-S | 20 | 2307.095 | 60.000 | -222.160 | 0.0 | 42.3 | not |
| F036-H | 20 | 2308.739 | 60.000 | -221.930 | 0.0 | 40.8 | not |
| F036-S | 20 | 2304.169 | 60.000 | -221.756 | 0.0 | 27.9 | not |
| F037-H | 20 | 2315.125 | 60.000 | -221.573 | 0.0 | 56.4 | not |
| F037-S | 20 | 2314.187 | 60.000 | -222.625 | 0.0 | 121.5 | not |
| F038-H | 20 | 2320.490 | 60.000 | -221.777 | 0.0 | 80.4 | not |
| F038-S | 20 | 2322.967 | 60.000 | -221.679 | 0.0 | 70.5 | not |
| F040-H | 20 | 2316.725 | 60.000 | -221.545 | 0.0 | 58.8 | not |
| F040-S | 20 | 2311.227 | 60.000 | -221.736 | 0.0 | 47.1 | not |

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|---|---|---|---|---|---|---|---|
| F041-H | 20 | 2408.536 | 60.000 | -221.997 | 0.0 | 30.0 | CATCH |
| F041-S | 20 | 2411.473 | 60.000 | -221.544 | 0.0 | 48.0 | CATCH |
| F042-H | 20 | 2310.454 | 60.000 | -222.068 | 0.0 | 45.6 | not |
| F042-S | 20 | 2310.135 | 60.000 | -221.920 | 0.0 | 48.0 | not |
| F043-H | 20 | 2313.666 | 60.000 | -222.405 | 0.0 | 54.9 | not |
| F043-S | 20 | 2303.716 | 60.000 | -221.555 | 0.0 | 54.6 | not |
| H001-H | 20 | 2308.571 | 60.000 | -221.847 | 0.0 | 66.0 | not |
| H002-H | 20 | 2303.629 | 60.000 | -221.874 | 0.0 | 46.2 | not |
| H003-H | 20 | 2301.686 | 60.000 | -222.127 | 0.0 | 90.3 | not |
| I001-H | 20 | 2315.699 | 60.000 | -222.834 | 0.0 | 108.0 | not |
| I001-S | 20 | 2439.189 | 60.000 | -221.512 | 0.0 | 140.4 | CATCH |
| P001-H | 20 | 2314.066 | 60.000 | -222.089 | 0.0 | 57.0 | not |
| P001-S | 20 | 2307.293 | 60.000 | -221.630 | 36.0 | 66.3 | not |
| P002-H | 20 | 2312.597 | 60.000 | -222.741 | 0.0 | 84.3 | not |
| P002-S | 20 | 2305.992 | 60.000 | -221.570 | 0.0 | 115.2 | not |
| P003-H | 20 | 2294.086 | 60.000 | -221.822 | 0.0 | 32.7 | not |
| P003-S | 20 | 2299.544 | 60.000 | -221.559 | 0.0 | 31.5 | not |
| P004-H | 20 | 2309.783 | 60.000 | -221.784 | 0.0 | 88.8 | not |
| P004-S | 20 | 2308.732 | 60.000 | -222.039 | 0.0 | 37.2 | not |
| P005-H | 20 | 2306.174 | 60.000 | -222.135 | 90.0 | 54.9 | not |
| P005-S | 20 | 2310.441 | 60.000 | -221.536 | 81.0 | 62.1 | not |
| P006-H | 20 | 2437.174 | 60.000 | -221.681 | 0.0 | 87.9 | CATCH |
| P006-S | 20 | 2300.220 | 60.000 | -222.480 | 0.0 | 91.2 | not |
| P007-H | 20 | 2307.487 | 60.000 | -221.719 | 0.0 | 30.9 | not |
| P007-S | 20 | 2300.946 | 60.000 | -221.595 | 0.0 | 41.4 | not |
| P008-H | 20 | 2414.223 | 60.000 | -221.911 | 0.0 | 55.8 | CATCH |
| P008-S | 20 | 2401.137 | 60.000 | -221.756 | 0.0 | 113.4 | CATCH |
| P009-H | 20 | 2304.915 | 60.000 | -222.577 | 0.0 | 93.9 | not |
| P009-S | 20 | 2303.186 | 60.000 | -222.940 | 0.0 | 149.4 | not |
| P010-H | 20 | 2320.694 | 60.000 | -221.962 | 0.0 | 68.4 | not |
| P010-S | 20 | 2315.165 | 60.000 | -222.664 | 0.0 | 70.2 | not |

## Task Room 21 Reduced Data

| File | Room | X | Y | Z | Rotate | Speed | RESULT |
|---|---|---|---|---|---|---|---|
| A001-H | 21 | 2823.500 | 125.000 | -130.844 | 0.0 | 60.6 | FLY |
| A002-H | 21 | 2822.990 | 60.000 | -22.575 | 0.0 | 117.9 | no |
| A003-H | 21 | 2823.850 | 60.000 | -18.770 | 90.0 | 54.6 | m/b |
| A004-H | 21 | 2823.132 | 125.000 | -128.117 | 0.0 | 80.4 | FLY |
| A005-H | 21 | 2824.244 | 125.000 | -123.659 | 0.0 | 71.7 | FLY |
| B001-H | 21 | 2824.143 | 60.000 | -34.758 | 0.0 | 17.1 | no |
| B001-S | 21 | 2823.797 | 60.000 | -33.097 | 0.0 | 36.3 | no |
| B002-H | 21 | 2823.057 | 60.000 | -22.951 | 0.0 | 79.8 | no |
| B002-S | 21 | 2822.913 | 60.000 | -15.177 | 0.0 | 107.7 | no |
| B003-H | 21 | 2823.783 | 60.000 | -31.175 | 0.0 | 54.3 | no |
| B003-S | 21 | 2824.001 | 103.000 | -123.905 | 0.0 | 97.5 | FLY |
| B004-H | 21 | 2823.917 | 125.000 | -134.015 | 0.0 | 53.7 | FLY |
| B004-S | 21 | 2824.201 | 125.000 | -133.014 | 0.0 | 93.3 | FLY |
| B005-H | 21 | 2823.968 | 60.000 | -40.078 | 0.0 | 31.5 | no |
| B005-S | 21 | 2824.174 | 60.000 | -33.604 | 0.0 | 31.8 | no |
| F001-H | 21 | 2824.113 | 125.000 | -123.836 | 0.0 | 35.4 | FLY |
| F001-S | 21 | 2823.995 | 125.000 | -127.219 | 0.0 | 78.9 | FLY |
| F002-H | 21 | 2823.232 | 125.000 | -143.341 | 0.0 | 65.7 | FLY |
| F002-S | 21 | 2823.501 | 60.000 | -33.161 | 0.0 | 78.0 | no |
| F003-H | 21 | 2823.727 | 125.000 | -137.722 | 0.0 | 113.4 | FLY |
| F003-S | 21 | 2823.399 | 125.000 | -119.484 | 0.0 | 146.7 | FLY |
| F004-H | 21 | 2824.055 | 60.000 | -23.310 | 0.0 | 93.3 | no |
| F004-S | 21 | 2823.692 | 60.000 | -27.377 | 0.0 | 95.7 | no |
| F005-H | 21 | 2822.685 | 125.000 | -135.549 | 0.0 | 121.2 | FLY |
| F005-S | 21 | 2822.221 | 125.000 | -114.447 | 0.0 | 133.2 | FLY |

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|---|---|---|---|---|---|---|---|
| F006-H | 21 | 2822.670 | 119.000 | -131.914 | 0.0 | 146.7 | FLY |
| F006-S | 21 | 2824.177 | 125.000 | -127.682 | 0.0 | 94.5 | FLY |
| F007-H | 21 | 2823.382 | 125.000 | -127.038 | 0.0 | 63.6 | FLY |
| F007-S | 21 | 2822.507 | 125.000 | -116.789 | 0.0 | 105.6 | FLY |
| F008-H | 21 | 2823.826 | 125.000 | -120.421 | 0.0 | 53.1 | FLY |
| F008-S | 21 | 2824.174 | 125.000 | -122.583 | 0.0 | 53.4 | FLY |
| F009-H | 21 | 2822.751 | 119.000 | -119.152 | 0.0 | 126.9 | FLY |
| F009-S | 21 | 2823.261 | 98.000 | -113.548 | 0.0 | 150.0 | FLY |
| F010-H | 21 | 2823.108 | 125.000 | -133.159 | 0.0 | 77.1 | FLY |
| F010-S | 21 | 2823.881 | 60.000 | -15.205 | 0.0 | 127.5 | no |
| F011-H | 21 | 2824.000 | 125.000 | -124.858 | 0.0 | 34.8 | FLY |
| F011-S | 21 | 2823.302 | 60.000 | -17.883 | 0.0 | 78.3 | no |
| F012-H | 21 | 2822.888 | 60.000 | -36.157 | 0.0 | 89.1 | no |
| F012-S | 21 | 2823.560 | 125.000 | -118.693 | 0.0 | 113.7 | FLY |
| F013-H | 21 | 2822.940 | 60.000 | -24.662 | 0.0 | 91.8 | no |
| F013-S | 21 | 2823.463 | 60.000 | -24.804 | 0.0 | 149.7 | no |
| F014-H | 21 | 2823.494 | 125.000 | -123.874 | 0.0 | 58.5 | FLY |
| F014-S | 21 | 2823.365 | 125.000 | -122.433 | 0.0 | 67.5 | FLY |
| F015-H | 21 | 2823.370 | 60.000 | -35.714 | 0.0 | 84.6 | no |
| F015-S | 21 | 2822.815 | 125.000 | -123.634 | 0.0 | 141.6 | FLY |
| F016-H | 21 | 2823.466 | 125.000 | -124.351 | 0.0 | 49.8 | FLY |
| F016-S | 21 | 2823.229 | 81.000 | -123.727 | 0.0 | 68.4 | FLY |
| F017-H | 21 | 2823.412 | 60.000 | -122.555 | 90.0 | 54.0 | m/b |
| F017-S | 21 | 2823.655 | 73.000 | -129.527 | 0.0 | 84.9 | FLY |
| F018-H | 21 | 2823.871 | 115.000 | -130.772 | 0.0 | 50.4 | FLY |
| F018-S | 21 | 2823.875 | 125.000 | -118.171 | 0.0 | 70.5 | FLY |
| F019-H | 21 | 2824.128 | 125.000 | -135.806 | 0.0 | 53.7 | FLY |
| F019-S | 21 | 2823.471 | 99.000 | -129.828 | 0.0 | 101.4 | FLY |
| F020-H | 21 | 2823.106 | 125.000 | -120.495 | 0.0 | 84.6 | FLY |
| F020-S | 21 | 2824.245 | 125.000 | -118.980 | 0.0 | 107.7 | FLY |
| F021-H | 21 | 2823.113 | 60.000 | -18.164 | 0.0 | 77.1 | no |
| F021-S | 21 | 2822.545 | 125.000 | -114.209 | 0.0 | 114.3 | FLY |
| F022-H | 21 | 2822.775 | 60.000 | -31.484 | 0.0 | 93.3 | no |
| F022-S | 21 | 2823.030 | 60.000 | -30.363 | 0.0 | 77.4 | no |
| F023-H | 21 | 2824.206 | 125.000 | -115.042 | 0.0 | 58.8 | FLY |
| F023-S | 21 | 2823.442 | 60.000 | -111.872 | 90.0 | 99.3 | m/b |
| F024-H | 21 | 2823.525 | 125.000 | -137.223 | 0.0 | 51.0 | FLY |
| F024-S | 21 | 2823.789 | 60.000 | -27.955 | 0.0 | 66.9 | no |
| F025-H | 21 | 2823.813 | 125.000 | -124.893 | 0.0 | 61.8 | FLY |
| F025-S | 21 | 2823.090 | 125.000 | -125.747 | 0.0 | 77.1 | FLY |
| F026-H | 21 | 2823.072 | 60.000 | -26.934 | 0.0 | 75.3 | no |
| F026-S | 21 | 2823.637 | 125.000 | -117.171 | 0.0 | 95.4 | FLY |
| F027-H | 21 | 2824.186 | 60.000 | -29.965 | 0.0 | 85.5 | no |
| F027-S | 21 | 2824.127 | 125.000 | -123.326 | 0.0 | 123.0 | FLY |
| F028-H | 21 | 2824.113 | 60.000 | -32.282 | 90.0 | 37.8 | m/b |
| F028-S | 21 | 2822.881 | 60.000 | -123.205 | 90.0 | 138.0 | m/b |
| F029-H | 21 | 2823.903 | 117.000 | -116.163 | 0.0 | 74.7 | FLY |
| F029-S | 21 | 2823.416 | 125.000 | -120.659 | 0.0 | 100.2 | FLY |
| F030-H | 21 | 2823.642 | 125.000 | -131.352 | 0.0 | 91.2 | FLY |
| F030-S | 21 | 2823.379 | 125.000 | -128.593 | 0.0 | 89.4 | FLY |
| F031-H | 21 | 2824.036 | 60.000 | -30.045 | 0.0 | 54.3 | no |
| F031-S | 21 | 2823.952 | 125.000 | -122.013 | 0.0 | 87.3 | FLY |
| F032-H | 21 | 2822.455 | 125.000 | -132.992 | 0.0 | 120.3 | FLY |
| F032-S | 21 | 2824.248 | 119.000 | -102.669 | 0.0 | 115.5 | FLY |
| F033-H | 21 | 2824.005 | 60.000 | -30.284 | 0.0 | 145.2 | no |
| F033-S | 21 | 2823.821 | 124.000 | -124.535 | 0.0 | 150.0 | FLY |
| F034-H | 21 | 2821.888 | 111.000 | -134.820 | 0.0 | 146.7 | FLY |
| F034-S | 21 | 2823.978 | 126.000 | -123.632 | 0.0 | 126.6 | FLY |
| F035-H | 21 | 2823.814 | 60.000 | -30.670 | 90.0 | 79.8 | m/b |
| F035-S | 21 | 2823.775 | 83.000 | -116.973 | 0.0 | 54.9 | FLY |

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|---|---|---|---|---|---|---|---|
| F036-H | 21 | 2823.384 | 125.000 | -125.636 | 0.0 | 58.8 | FLY |
| F036-S | 21 | 2824.244 | 125.000 | -123.294 | 0.0 | 43.8 | FLY |
| F037-H | 21 | 2823.807 | 60.000 | -27.520 | 0.0 | 104.4 | no |
| F037-S | 21 | 2823.605 | 109.000 | -131.283 | 0.0 | 129.6 | FLY |
| F038-H | 21 | 2823.969 | 60.000 | -126.009 | 0.0 | 81.9 | no |
| F038-S | 21 | 2824.054 | 102.000 | -116.274 | 0.0 | 74.4 | FLY |
| F040-H | 21 | 2823.886 | 125.000 | -128.647 | 0.0 | 77.4 | FLY |
| F040-S | 21 | 2823.870 | 125.000 | -114.805 | 0.0 | 54.0 | FLY |
| F041-H | 21 | 2823.827 | 60.000 | -26.446 | 0.0 | 51.0 | no |
| F041-S | 21 | 2823.729 | 60.000 | -117.838 | 0.0 | 72.6 | no |
| F042-H | 21 | 2824.235 | 60.000 | -34.552 | 90.0 | 54.6 | m/b |
| F042-S | 21 | 2823.483 | 60.000 | -29.325 | 0.0 | 47.4 | no |
| F043-H | 21 | 2823.990 | 60.000 | -30.466 | 0.0 | 77.1 | no |
| F043-S | 21 | 2823.950 | 125.000 | -127.731 | 0.0 | 69.9 | FLY |
| H001-H | 21 | 2822.789 | 60.000 | -18.783 | 0.0 | 108.9 | no |
| H002-H | 21 | 2823.530 | 60.000 | -128.928 | 0.0 | 59.4 | no |
| H003-H | 21 | 2823.806 | 60.000 | -15.534 | 0.0 | 109.8 | no |
| I001-H | 21 | 2822.904 | 99.000 | -132.566 | 0.0 | 108.9 | FLY |
| I001-S | 21 | 2823.747 | 123.000 | -128.808 | 0.0 | 78.6 | FLY |
| P001-H | 21 | 2823.548 | 60.000 | -36.446 | 0.0 | 80.4 | no |
| P001-S | 21 | 2824.044 | 166.000 | -120.538 | 0.0 | 63.9 | FLY |
| P002-H | 21 | 2823.391 | 60.000 | -35.954 | 0.0 | 72.3 | no |
| P002-S | 21 | 2824.011 | 60.000 | -24.649 | 0.0 | 136.5 | no |
| P003-H | 21 | 2824.235 | 204.000 | -114.833 | 0.0 | 27.0 | FLY |
| P003-S | 21 | 2824.192 | 60.000 | -15.634 | 0.0 | 27.9 | no |
| P004-H | 21 | 2823.501 | 198.000 | -123.022 | 0.0 | 84.0 | FLY |
| P004-S | 21 | 2824.004 | 60.000 | -23.071 | 0.0 | 53.7 | no |
| P005-H | 21 | 2823.989 | 194.000 | -119.542 | 0.0 | 47.7 | FLY |
| P005-S | 21 | 2823.063 | 222.000 | -117.776 | 0.0 | 70.8 | FLY |
| P006-H | 21 | 2824.171 | 186.000 | -133.314 | 0.0 | 53.1 | FLY |
| P006-S | 21 | 2823.265 | 142.000 | -109.524 | 0.0 | 85.2 | FLY |
| P007-H | 21 | 2823.767 | 60.000 | -36.739 | 0.0 | 42.0 | no |
| P007-S | 21 | 2823.765 | 60.000 | -29.829 | 0.0 | 45.6 | no |
| P008-H | 21 | 2823.313 | 60.000 | -28.569 | 0.0 | 75.9 | no |
| P008-S | 21 | 2823.792 | 60.000 | -29.550 | 0.0 | 51.9 | no |
| P009-H | 21 | 2822.753 | 60.000 | -32.115 | 0.0 | 139.2 | no |
| P009-S | 21 | 2822.765 | 114.000 | -106.748 | 0.0 | 148.8 | FLY |
| P010-H | 21 | 2824.164 | 60.000 | -25.785 | 0.0 | 60.0 | no |
| P010-S | 21 | 2824.118 | 60.000 | -28.200 | 0.0 | 70.8 | no |

## Task Room 22 Reduced Data

| File | Room | X | Y | Z | Rotate | Speed | RESULT |
|---|---|---|---|---|---|---|---|
| A001-H | 22 | 2952.427 | 60.000 | -563.872 | 0.0 | 51.3 | no |
| A002-H | 22 | 2946.809 | 60.000 | -563.168 | 0.0 | 138.3 | no |
| A003-H | 22 | 2947.121 | 60.000 | -563.536 | 0.0 | 60.9 | no |
| A004-H | 22 | 2956.789 | 60.000 | -563.813 | 0.0 | 85.8 | no |
| A005-H | 22 | 2950.083 | 60.000 | -563.010 | 0.0 | 93.3 | no |
| B001-H | 22 | 2965.422 | 60.000 | -564.345 | 0.0 | 20.7 | no |
| B001-S | 22 | 2965.515 | 60.000 | -564.469 | 90.0 | 24.3 | ROTATE |
| B002-H | 22 | 2979.879 | 60.000 | -563.717 | 90.0 | 81.0 | ROTATE |
| B002-S | 22 | 2971.787 | 60.000 | -564.186 | 90.0 | 83.7 | ROTATE |
| B003-H | 22 | 2393.655 | 60.000 | -563.895 | 0.0 | 46.5 | no |
| B003-S | 22 | 2966.589 | 60.000 | -563.638 | 0.0 | 71.7 | no |
| B004-H | 22 | 2961.566 | 60.000 | -563.651 | 0.0 | 61.5 | no |
| B004-S | 22 | 2965.220 | 60.000 | -563.381 | 81.0 | 70.5 | ROTATE |
| B005-H | 22 | 2966.273 | 60.000 | -564.060 | 0.0 | 43.8 | no |
| B005-S | 22 | 2966.240 | 60.000 | -563.253 | 0.0 | 76.5 | no |
| F001-H | 22 | 2965.466 | 60.000 | -564.220 | 90.0 | 24.6 | ROTATE |
| F001-S | 22 | 2967.067 | 60.000 | -563.809 | 90.0 | 60.3 | ROTATE |

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|---|---|---|---|---|---|---|---|
| F002-H | 22 | 2958.111 | 60.000 | -563.986 | 90.0 | 75.6 | ROTATE |
| F002-S | 22 | 2970.015 | 60.000 | -563.674 | 90.0 | 90.0 | ROTATE |
| F003-H | 22 | 2962.061 | 60.000 | -564.186 | 90.0 | 84.3 | ROTATE |
| F003-S | 22 | 2962.943 | 60.000 | -562.986 | 90.0 | 141.6 | ROTATE |
| F004-H | 22 | 2974.852 | 60.000 | -564.006 | 0.0 | 97.2 | no |
| F004-S | 22 | 2968.130 | 60.000 | -563.093 | 0.0 | 112.5 | no |
| F005-H | 22 | 2966.324 | 60.000 | -563.883 | 90.0 | 88.8 | ROTATE |
| F005-S | 22 | 2972.083 | 60.000 | -564.343 | 90.0 | 134.1 | ROTATE |
| F006-H | 22 | 2956.872 | 60.000 | -563.379 | 93.0 | 146.7 | ROTATE |
| F006-S | 22 | 2968.404 | 60.000 | -564.391 | 90.0 | 89.1 | ROTATE |
| F007-H | 22 | 2963.373 | 60.000 | -563.949 | 90.0 | 54.0 | ROTATE |
| F007-S | 22 | 2966.086 | 60.000 | -563.013 | 90.0 | 102.0 | ROTATE |
| F008-H | 22 | 2963.739 | 60.000 | -563.928 | 90.0 | 39.9 | ROTATE |
| F008-S | 22 | 2964.292 | 98.000 | -564.134 | 0.0 | 35.1 | m/b |
| F009-H | 22 | 2961.906 | 60.000 | -564.069 | 90.0 | 114.3 | ROTATE |
| F009-S | 22 | 2958.607 | 60.000 | -562.322 | 90.0 | 150.0 | ROTATE |
| F010-H | 22 | 2963.742 | 60.000 | -564.268 | 90.0 | 50.7 | ROTATE |
| F010-S | 22 | 2982.016 | 60.000 | -564.221 | 90.0 | 130.5 | ROTATE |
| F011-H | 22 | 2966.012 | 60.000 | -564.452 | 90.0 | 43.2 | ROTATE |
| F011-S | 22 | 2966.864 | 60.000 | -564.178 | 90.0 | 58.2 | ROTATE |
| F012-H | 22 | 2962.447 | 60.000 | -563.597 | 0.0 | 94.5 | no |
| F012-S | 22 | 2965.832 | 60.000 | -563.071 | 0.0 | 112.5 | no |
| F013-H | 22 | 2981.476 | 60.000 | -563.607 | 90.0 | 94.2 | ROTATE |
| F013-S | 22 | 2972.070 | 60.000 | -562.181 | 0.0 | 150.0 | no |
| F014-H | 22 | 2966.436 | 60.000 | -563.952 | 0.0 | 56.4 | no |
| F014-S | 22 | 2967.666 | 60.000 | -563.800 | 0.0 | 46.5 | no |
| F015-H | 22 | 2961.991 | 60.000 | -563.333 | 90.0 | 89.4 | ROTATE |
| F015-S | 22 | 2967.225 | 60.000 | -562.806 | 90.0 | 133.5 | ROTATE |
| F016-H | 22 | 2959.901 | 60.000 | -564.386 | 90.0 | 39.0 | ROTATE |
| F016-S | 22 | 2968.608 | 60.000 | -564.236 | 90.0 | 36.0 | ROTATE |
| F017-H | 22 | 2963.451 | 60.000 | -564.021 | 90.0 | 42.3 | ROTATE |
| F017-S | 22 | 2967.615 | 60.000 | -563.936 | 60.0 | 89.1 | ROTATE |
| F018-H | 22 | 2962.766 | 60.000 | -563.852 | 90.0 | 42.9 | ROTATE |
| F018-S | 22 | 2968.873 | 60.000 | -564.159 | 90.0 | 64.8 | ROTATE |
| F019-H | 22 | 2969.482 | 60.000 | -564.340 | 90.0 | 62.1 | ROTATE |
| F019-S | 22 | 2964.419 | 60.000 | -563.976 | 75.0 | 120.9 | ROTATE |
| F020-H | 22 | 2962.224 | 60.000 | -564.228 | 90.0 | 81.9 | ROTATE |
| F020-S | 22 | 2969.871 | 60.000 | -563.027 | 90.0 | 116.1 | ROTATE |
| F021-H | 22 | 2977.573 | 60.000 | -563.323 | 90.0 | 83.1 | ROTATE |
| F021-S | 22 | 2963.451 | 60.000 | -563.229 | 0.0 | 120.6 | no |
| F022-H | 22 | 2962.768 | 60.000 | -563.591 | 90.0 | 104.1 | ROTATE |
| F022-S | 22 | 2973.725 | 60.000 | -563.455 | 63.0 | 93.0 | ROTATE |
| F023-H | 22 | 2980.034 | 60.000 | -563.646 | 0.0 | 70.8 | no |
| F023-S | 22 | 2968.715 | 60.000 | -564.000 | 0.0 | 44.4 | no |
| F024-H | 22 | 2961.241 | 60.000 | -563.861 | 90.0 | 51.6 | ROTATE |
| F024-S | 22 | 2963.365 | 60.000 | -563.934 | 90.0 | 64.2 | ROTATE |
| F025-H | 22 | 2968.510 | 60.000 | -564.351 | 90.0 | 76.8 | ROTATE |
| F025-S | 22 | 2967.362 | 60.000 | -564.265 | 0.0 | 81.0 | no |
| F026-H | 22 | 2962.866 | 60.000 | -563.787 | 90.0 | 80.1 | ROTATE |
| F026-S | 22 | 2967.516 | 60.000 | -562.947 | 90.0 | 104.7 | ROTATE |
| F027-H | 22 | 2966.800 | 60.000 | -564.236 | 90.0 | 72.3 | ROTATE |
| F027-S | 22 | 2969.208 | 60.000 | -563.760 | 54.0 | 109.8 | ROTATE |
| F028-H | 22 | 2962.319 | 60.000 | -563.426 | 90.0 | 68.7 | ROTATE |
| F028-S | 22 | 2965.803 | 60.000 | -564.457 | 84.0 | 150.0 | ROTATE |
| F029-H | 22 | 2959.647 | 60.000 | -564.230 | 90.0 | 87.9 | ROTATE |
| F029-S | 22 | 2967.731 | 60.000 | -564.447 | 90.0 | 48.3 | ROTATE |
| F030-H | 22 | 2964.014 | 60.000 | -563.815 | 90.0 | 86.1 | ROTATE |
| F030-S | 22 | 2969.801 | 60.000 | -563.756 | 90.0 | 87.9 | ROTATE |
| F031-H | 22 | 2963.032 | 60.000 | -564.182 | 87.0 | 38.7 | ROTATE |
| F031-S | 22 | 2967.378 | 60.000 | -563.767 | 48.0 | 72.6 | ROTATE |

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|---|---|---|---|---|---|---|---|
| F032-H | 22 | 2965.665 | 60.000 | -563.103 | 90.0 | 114.9 | ROTATE |
| F032-S | 22 | 2965.000 | 60.000 | -564.205 | 90.0 | 125.1 | ROTATE |
| F033-H | 22 | 2972.583 | 60.000 | -562.844 | 90.0 | 135.9 | ROTATE |
| F033-S | 22 | 2969.069 | 60.000 | -564.367 | 0.0 | 132.0 | no |
| F034-H | 22 | 2956.455 | 60.000 | -563.249 | 90.0 | 120.6 | ROTATE |
| F034-S | 22 | 2965.241 | 60.000 | -563.859 | 81.0 | 113.4 | ROTATE |
| F035-H | 22 | 2967.721 | 60.000 | -563.963 | 90.0 | 102.0 | ROTATE |
| F035-S | 22 | 2968.572 | 60.000 | -564.006 | 90.0 | 44.4 | ROTATE |
| F036-H | 22 | 2966.112 | 60.000 | -564.245 | 90.0 | 66.6 | ROTATE |
| F036-S | 22 | 2965.672 | 60.000 | -564.270 | 54.0 | 38.4 | ROTATE |
| F037-H | 22 | 2958.912 | 60.000 | -563.640 | 90.0 | 127.2 | ROTATE |
| F037-S | 22 | 2969.933 | 60.000 | -564.056 | 90.0 | 129.0 | ROTATE |
| F038-H | 22 | 2976.086 | 60.000 | -563.961 | 27.0 | 71.1 | ROTATE |
| F038-S | 22 | 2973.047 | 60.000 | -563.411 | 90.0 | 77.4 | ROTATE |
| F040-H | 22 | 2962.831 | 60.000 | -563.341 | 90.0 | 72.6 | ROTATE |
| F040-S | 22 | 2970.194 | 60.000 | -564.440 | 90.0 | 62.1 | ROTATE |
| F041-H | 22 | 2971.829 | 60.000 | -564.323 | 0.0 | 64.8 | no |
| F041-S | 22 | 2964.954 | 60.000 | -563.630 | 81.0 | 94.5 | ROTATE |
| F042-H | 22 | 2960.038 | 60.000 | -564.469 | 90.0 | 60.9 | ROTATE |
| F042-S | 22 | 2966.296 | 60.000 | -563.809 | 0.0 | 59.1 | no |
| F043-H | 22 | 2964.652 | 60.000 | -563.849 | 0.0 | 45.0 | no |
| F043-S | 22 | 2969.653 | 60.000 | -564.378 | 90.0 | 62.4 | ROTATE |
| H001-H | 22 | 2968.959 | 60.000 | -564.433 | 90.0 | 86.1 | ROTATE |
| H002-H | 22 | 2968.491 | 60.000 | -563.745 | 0.0 | 69.3 | no |
| H003-H | 22 | 2961.708 | 60.000 | -562.852 | 90.0 | 120.3 | ROTATE |
| I001-H | 22 | 2961.843 | 60.000 | -563.889 | 36.0 | 76.8 | ROTATE |
| I001-S | 22 | 2963.992 | 60.000 | -563.753 | 81.0 | 96.6 | ROTATE |
| P001-H | 22 | 2964.661 | 60.000 | -564.048 | 90.0 | 83.4 | ROTATE |
| P001-S | 22 | 2967.095 | 60.000 | -563.330 | 90.0 | 90.6 | ROTATE |
| P002-H | 22 | 2964.895 | 60.000 | -563.784 | 90.0 | 56.7 | ROTATE |
| P002-S | 22 | 2976.147 | 60.000 | -564.436 | 90.0 | 132.0 | ROTATE |
| P003-H | 22 | 2965.696 | 60.000 | -564.402 | 0.0 | 35.1 | no |
| P003-S | 22 | 2968.864 | 60.000 | -564.219 | 90.0 | 30.3 | ROTATE |
| P004-H | 22 | 2959.426 | 60.000 | -564.393 | 90.0 | 80.4 | ROTATE |
| P004-S | 22 | 2964.816 | 60.000 | -563.983 | 72.0 | 45.0 | ROTATE |
| P005-H | 22 | 2967.846 | 60.000 | -564.240 | 90.0 | 45.0 | ROTATE |
| P005-S | 22 | 2970.775 | 60.000 | -564.470 | 90.0 | 39.3 | ROTATE |
| P006-H | 22 | 2968.035 | 60.000 | -563.491 | 0.0 | 101.4 | no |
| P006-S | 22 | 2963.388 | 60.000 | -563.706 | 0.0 | 89.1 | no |
| P007-H | 22 | 2974.674 | 60.000 | -564.420 | 90.0 | 35.7 | ROTATE |
| P007-S | 22 | 2970.590 | 60.000 | -564.259 | 90.0 | 32.7 | ROTATE |
| P008-H | 22 | 2967.889 | 60.000 | -563.897 | 0.0 | 59.4 | no |
| P008-S | 22 | 2970.906 | 60.000 | -562.727 | 0.0 | 110.7 | no |
| P009-H | 22 | 2962.952 | 60.000 | -562.738 | 0.0 | 150.0 | no |
| P009-S | 22 | 2966.646 | 60.000 | -564.319 | 0.0 | 142.5 | no |
| P010-H | 22 | 2969.954 | 60.000 | -563.568 | 90.0 | 74.1 | ROTATE |
| P010-S | 22 | 2972.250 | 60.000 | -563.834 | 39.0 | 64.8 | ROTATE |

## Task Room 23 Reduced Data

| File | Room | X | Y | Z | Rotate | Speed | RESULT |
|---|---|---|---|---|---|---|---|
| A001-H | 23 | 3412.803 | 60.000 | -609.287 | 0.0 | 67.5 | not |
| A002-H | 23 | 3413.700 | 60.000 | -626.752 | 0.0 | 122.7 | not |
| A003-H | 23 | 3413.063 | 60.000 | -617.006 | 0.0 | 55.2 | not |
| A004-H | 23 | 3413.633 | 60.000 | -633.740 | 0.0 | 60.3 | not |
| A005-H | 23 | 3412.712 | 60.000 | -623.911 | 0.0 | 70.5 | not |
| B001-H | 23 | 3413.706 | 60.000 | -737.003 | 0.0 | 14.1 | CATCH |
| B001-S | 23 | 3413.627 | 60.000 | -726.988 | 0.0 | 35.4 | CATCH |
| B002-H | 23 | 3413.628 | 60.000 | -735.318 | 0.0 | 66.0 | CATCH |
| B002-S | 23 | 3412.340 | 60.000 | -732.273 | 0.0 | 95.4 | CATCH |

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|---|---|---|---|---|---|---|---|
| B003-H | 23 | 3413.168 | 60.000 | -733.253 | 0.0 | 46.5 | CATCH |
| B003-S | 23 | 3413.608 | 60.000 | -733.339 | 0.0 | 73.2 | CATCH |
| B004-H | 23 | 3413.190 | 60.000 | -741.513 | 0.0 | 60.9 | CATCH |
| B004-S | 23 | 3412.898 | 60.000 | -734.183 | 0.0 | 87.9 | CATCH |
| B005-H | 23 | 3413.661 | 60.000 | -638.180 | 0.0 | 36.9 | not |
| B005-S | 23 | 3413.468 | 60.000 | -723.120 | 0.0 | 31.5 | CATCH |
| F001-H | 23 | 3413.154 | 60.000 | -732.510 | 0.0 | 43.5 | CATCH |
| F001-S | 23 | 3413.307 | 60.000 | -731.785 | 0.0 | 63.0 | CATCH |
| F002-H | 23 | 3412.527 | 60.000 | -737.037 | 0.0 | 82.5 | CATCH |
| F002-S | 23 | 3412.937 | 60.000 | -728.053 | 0.0 | 52.5 | CATCH |
| F003-H | 23 | 3413.726 | 60.000 | -729.652 | 0.0 | 86.7 | CATCH |
| F003-S | 23 | 3413.297 | 60.000 | -719.854 | 0.0 | 100.5 | CATCH |
| F004-H | 23 | 3412.976 | 60.000 | -719.252 | 0.0 | 96.3 | CATCH |
| F004-S | 23 | 3411.970 | 60.000 | -724.463 | 0.0 | 119.1 | CATCH |
| F005-H | 23 | 3413.357 | 60.000 | -724.467 | 0.0 | 63.9 | CATCH |
| F005-S | 23 | 3412.885 | 60.000 | -725.418 | 0.0 | 131.4 | CATCH |
| F006-H | 23 | 3413.666 | 60.000 | -733.648 | 0.0 | 143.7 | CATCH |
| F006-S | 23 | 3412.711 | 60.000 | -727.522 | 0.0 | 96.0 | CATCH |
| F007-H | 23 | 3413.636 | 60.000 | -725.671 | 90.0 | 63.9 | CATCH |
| F007-S | 23 | 3413.409 | 60.000 | -721.586 | 0.0 | 103.2 | CATCH |
| F008-H | 23 | 3413.446 | 60.000 | -733.933 | 0.0 | 48.3 | CATCH |
| F008-S | 23 | 3413.707 | 60.000 | -731.439 | 0.0 | 45.6 | CATCH |
| F009-H | 23 | 3411.910 | 60.000 | -734.006 | 90.0 | 118.2 | CATCH |
| F009-S | 23 | 3412.782 | 60.000 | -722.535 | 0.0 | 150.0 | CATCH |
| F010-H | 23 | 3412.700 | 60.000 | -725.512 | 0.0 | 79.8 | CATCH |
| F010-S | 23 | 3413.344 | 60.000 | -733.307 | 0.0 | 64.2 | CATCH |
| F011-H | 23 | 3413.733 | 60.000 | -737.619 | 0.0 | 39.0 | CATCH |
| F011-S | 23 | 3412.952 | 60.000 | -730.686 | 0.0 | 64.2 | CATCH |
| F012-H | 23 | 3413.310 | 60.000 | -729.126 | 0.0 | 91.2 | CATCH |
| F012-S | 23 | 3412.838 | 60.000 | -721.655 | 0.0 | 126.0 | CATCH |
| F013-H | 23 | 3412.999 | 60.000 | -730.212 | 0.0 | 93.0 | CATCH |
| F013-S | 23 | 3413.538 | 60.000 | -723.399 | 0.0 | 139.5 | CATCH |
| F014-H | 23 | 3413.569 | 60.000 | -730.651 | 0.0 | 58.5 | CATCH |
| F014-S | 23 | 3412.954 | 60.000 | -731.557 | 0.0 | 53.7 | CATCH |
| F015-H | 23 | 3413.528 | 60.000 | -730.480 | 90.0 | 68.7 | CATCH |
| F015-S | 23 | 3412.550 | 60.000 | -723.447 | 0.0 | 148.2 | CATCH |
| F016-H | 23 | 3413.309 | 60.000 | -615.870 | 90.0 | 34.2 | not |
| F016-S | 23 | 3413.347 | 60.000 | -628.159 | 0.0 | 41.7 | not |
| F017-H | 23 | 3412.969 | 60.000 | -735.409 | 0.0 | 49.2 | CATCH |
| F017-S | 23 | 3413.437 | 60.000 | -728.795 | 0.0 | 71.7 | CATCH |
| F018-H | 23 | 3413.350 | 60.000 | -727.340 | 0.0 | 37.2 | CATCH |
| F018-S | 23 | 3413.607 | 60.000 | -727.676 | 0.0 | 73.2 | CATCH |
| F019-H | 23 | 3413.117 | 60.000 | -729.074 | 0.0 | 65.7 | CATCH |
| F019-S | 23 | 3412.464 | 60.000 | -730.114 | 0.0 | 121.8 | CATCH |
| F020-H | 23 | 3413.530 | 60.000 | -731.063 | 0.0 | 84.3 | CATCH |
| F020-S | 23 | 3412.455 | 60.000 | -726.862 | 0.0 | 113.4 | CATCH |
| F021-H | 23 | 3413.501 | 60.000 | -729.445 | 0.0 | 81.3 | CATCH |
| F021-S | 23 | 3412.014 | 60.000 | -726.070 | 0.0 | 117.3 | CATCH |
| F022-H | 23 | 3412.832 | 60.000 | -731.270 | 0.0 | 87.9 | CATCH |
| F022-S | 23 | 3412.985 | 60.000 | -733.388 | 0.0 | 88.8 | CATCH |
| F023-H | 23 | 3413.663 | 60.000 | -738.081 | 0.0 | 59.4 | CATCH |
| F023-S | 23 | 3413.218 | 60.000 | -735.656 | 0.0 | 47.7 | CATCH |
| F024-H | 23 | 3412.783 | 60.000 | -738.119 | 90.0 | 57.6 | CATCH |
| F024-S | 23 | 3413.377 | 60.000 | -735.212 | 0.0 | 71.4 | CATCH |
| F025-H | 23 | 3413.565 | 60.000 | -731.121 | 0.0 | 61.8 | CATCH |
| F025-S | 23 | 3412.915 | 60.000 | -731.378 | 0.0 | 81.0 | CATCH |
| F026-H | 23 | 3413.342 | 60.000 | -729.595 | 0.0 | 74.1 | CATCH |
| F026-S | 23 | 3413.257 | 60.000 | -732.178 | 0.0 | 90.3 | CATCH |
| F027-H | 23 | 3413.738 | 60.000 | -729.718 | 0.0 | 75.6 | CATCH |
| F027-S | 23 | 3413.518 | 60.000 | -731.193 | 0.0 | 103.5 | CATCH |

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|---|---|---|---|---|---|---|---|
| F028-H | 23 | 3413.684 | 60.000 | -732.483 | 0.0 | 87.0 | CATCH |
| F028-S | 23 | 3413.571 | 60.000 | -727.631 | 0.0 | 111.6 | CATCH |
| F029-H | 23 | 3413.408 | 60.000 | -620.767 | 0.0 | 36.9 | not |
| F029-S | 23 | 3413.725 | 60.000 | -733.311 | 0.0 | 51.3 | CATCH |
| F030-H | 23 | 3412.835 | 60.000 | -732.797 | 0.0 | 77.1 | CATCH |
| F030-S | 23 | 3413.556 | 60.000 | -728.394 | 0.0 | 59.1 | CATCH |
| F031-H | 23 | 3413.338 | 60.000 | -731.842 | 0.0 | 27.9 | CATCH |
| F031-S | 23 | 3412.826 | 60.000 | -728.996 | 0.0 | 56.1 | CATCH |
| F032-H | 23 | 3412.504 | 60.000 | -727.479 | 0.0 | 109.2 | CATCH |
| F032-S | 23 | 3412.664 | 60.000 | -729.679 | 0.0 | 114.9 | CATCH |
| F033-H | 23 | 3412.624 | 60.000 | -739.515 | 0.0 | 132.6 | CATCH |
| F033-S | 23 | 3413.391 | 60.000 | -729.508 | 0.0 | 133.2 | CATCH |
| F034-H | 23 | 3413.031 | 60.000 | -733.059 | 0.0 | 113.7 | CATCH |
| F034-S | 23 | 3413.557 | 60.000 | -733.591 | 0.0 | 121.8 | CATCH |
| F035-H | 23 | 3413.518 | 60.000 | -729.258 | 90.0 | 39.6 | CATCH |
| F035-S | 23 | 3413.339 | 60.000 | -727.453 | 0.0 | 47.7 | CATCH |
| F036-H | 23 | 3413.493 | 60.000 | -728.153 | 0.0 | 43.2 | CATCH |
| F036-S | 23 | 3413.325 | 60.000 | -734.150 | 0.0 | 28.2 | CATCH |
| F037-H | 23 | 3413.241 | 60.000 | -736.347 | 0.0 | 78.3 | CATCH |
| F037-S | 23 | 3412.162 | 60.000 | -731.955 | 0.0 | 123.3 | CATCH |
| F038-H | 23 | 3413.284 | 60.000 | -746.134 | 0.0 | 55.2 | CATCH |
| F038-S | 23 | 3412.974 | 60.000 | -738.329 | 0.0 | 65.1 | CATCH |
| F040-H | 23 | 3412.936 | 60.000 | -732.470 | 0.0 | 63.3 | CATCH |
| F040-S | 23 | 3413.396 | 60.000 | -732.588 | 0.0 | 48.6 | CATCH |
| F041-H | 23 | 3413.672 | 60.000 | -734.617 | 0.0 | 19.2 | CATCH |
| F041-S | 23 | 3413.343 | 60.000 | -722.990 | 0.0 | 85.2 | CATCH |
| F042-H | 23 | 3413.314 | 60.000 | -742.201 | 0.0 | 47.4 | CATCH |
| F042-S | 23 | 3413.114 | 60.000 | -732.177 | 0.0 | 48.0 | CATCH |
| F043-H | 23 | 3413.427 | 60.000 | -729.276 | 0.0 | 48.3 | CATCH |
| F043-S | 23 | 3413.556 | 60.000 | -728.567 | 0.0 | 56.4 | CATCH |
| H001-H | 23 | 3413.152 | 60.000 | -737.563 | 0.0 | 64.5 | CATCH |
| H002-H | 23 | 3413.220 | 60.000 | -740.166 | 0.0 | 54.3 | CATCH |
| H003-H | 23 | 3412.773 | 60.000 | -736.968 | 0.0 | 100.2 | CATCH |
| I001-H | 23 | 3413.455 | 60.000 | -725.894 | 90.0 | 66.9 | CATCH |
| I001-S | 23 | 3412.642 | 60.000 | -716.863 | 90.0 | 117.0 | CATCH |
| P001-H | 23 | 3412.795 | 60.000 | -728.618 | 0.0 | 69.0 | CATCH |
| P001-S | 23 | 3413.050 | 60.000 | -727.161 | 0.0 | 59.4 | CATCH |
| P002-H | 23 | 3413.697 | 60.000 | -731.308 | 0.0 | 51.6 | CATCH |
| P002-S | 23 | 3412.805 | 60.000 | -729.771 | 0.0 | 101.1 | CATCH |
| P003-H | 23 | 3413.308 | 60.000 | -750.255 | 0.0 | 30.6 | CATCH |
| P003-S | 23 | 3413.551 | 60.000 | -730.164 | 0.0 | 33.0 | CATCH |
| P004-H | 23 | 3413.520 | 60.000 | -740.026 | 0.0 | 68.4 | CATCH |
| P004-S | 23 | 3413.467 | 60.000 | -733.513 | 0.0 | 38.4 | CATCH |
| P005-H | 23 | 3413.148 | 60.000 | -735.435 | 90.0 | 36.0 | CATCH |
| P005-S | 23 | 3413.749 | 60.000 | -728.361 | 90.0 | 31.8 | CATCH |
| P006-H | 23 | 3413.279 | 60.000 | -748.359 | 0.0 | 83.7 | CATCH |
| P006-S | 23 | 3413.400 | 60.000 | -734.718 | 0.0 | 50.1 | CATCH |
| P007-H | 23 | 3412.936 | 60.000 | -734.974 | 0.0 | 53.7 | CATCH |
| P007-S | 23 | 3413.223 | 60.000 | -729.072 | 0.0 | 49.2 | CATCH |
| P008-H | 23 | 3413.345 | 60.000 | -735.083 | 0.0 | 50.4 | CATCH |
| P008-S | 23 | 3413.371 | 60.000 | -699.069 | 0.0 | 52.8 | CATCH |
| P009-H | 23 | 3412.848 | 60.000 | -725.902 | 0.0 | 87.6 | CATCH |
| P009-S | 23 | 3412.552 | 60.000 | -617.514 | 0.0 | 148.2 | not |
| P010-H | 23 | 3412.835 | 60.000 | -729.041 | 0.0 | 69.9 | CATCH |
| P010-S | 23 | 3413.641 | 60.000 | -732.239 | 0.0 | 63.9 | CATCH |

## Task Room 24 Reduced Data

| File | Room | X | Y | Z | Rotate | Speed | RESULT |
|---|---|---|---|---|---|---|---|
| A001-H | 24 | 3527.808 | 125.000 | -222.303 | 0.0 | 65.7 | FLY |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| A002-H | 24 | 3614.785 | 60.000 | -222.172 | 0.0 | 84.3 | no |
| A003-H | 24 | 3621.653 | 60.000 | -221.544 | 0.0 | 47.4 | no |
| A004-H | 24 | 3529.940 | 125.000 | -221.729 | 0.0 | 63.9 | FLY |
| A005-H | 24 | 3610.614 | 60.000 | -222.093 | 0.0 | 62.1 | no |
| B001-H | 24 | 3621.646 | 60.000 | -221.596 | 0.0 | 17.1 | no |
| B001-S | 24 | 3608.694 | 60.000 | -221.956 | 0.0 | 31.5 | no |
| B002-H | 24 | 3609.882 | 60.000 | -221.613 | 0.0 | 34.8 | no |
| B002-S | 24 | 3515.937 | 108.000 | -222.223 | 0.0 | 115.2 | FLY |
| B003-H | 24 | 3532.190 | 109.000 | -222.008 | 0.0 | 61.8 | FLY |
| B003-S | 24 | 3517.995 | 125.000 | -222.657 | 0.0 | 81.0 | FLY |
| B004-H | 24 | 3621.573 | 60.000 | -221.771 | 0.0 | 55.2 | no |
| B004-S | 24 | 3517.373 | 125.000 | -221.919 | 0.0 | 81.3 | FLY |
| B005-H | 24 | 3618.268 | 60.000 | -221.748 | 0.0 | 39.6 | no |
| B005-S | 24 | 3616.771 | 60.000 | -221.564 | 0.0 | 56.7 | no |
| F001-H | 24 | 3524.996 | 125.000 | -221.698 | 0.0 | 50.7 | FLY |
| F001-S | 24 | 3513.189 | 125.000 | -222.045 | 0.0 | 55.8 | FLY |
| F002-H | 24 | 3614.209 | 60.000 | -222.849 | 0.0 | 89.1 | no |
| F002-S | 24 | 3527.707 | 125.000 | -222.638 | 0.0 | 95.7 | FLY |
| F003-H | 24 | 3538.847 | 125.000 | -221.940 | 0.0 | 110.4 | FLY |
| F003-S | 24 | 3518.154 | 125.000 | -223.367 | 0.0 | 134.4 | FLY |
| F004-H | 24 | 3608.488 | 60.000 | -221.764 | 0.0 | 92.4 | no |
| F004-S | 24 | 3620.530 | 60.000 | -221.602 | 0.0 | 121.2 | no |
| F005-H | 24 | 3524.941 | 125.000 | -222.674 | 0.0 | 90.0 | FLY |
| F005-S | 24 | 3523.235 | 125.000 | -221.802 | 0.0 | 134.4 | FLY |
| F006-H | 24 | 3616.396 | 60.000 | -222.350 | 0.0 | 126.9 | no |
| F006-S | 24 | 3522.286 | 125.000 | -221.573 | 0.0 | 94.2 | FLY |
| F007-H | 24 | 3615.441 | 60.000 | -221.519 | 90.0 | 60.0 | m/b |
| F007-S | 24 | 3609.816 | 60.000 | -221.702 | 0.0 | 111.6 | no |
| F008-H | 24 | 3521.847 | 125.000 | -221.785 | 0.0 | 65.1 | FLY |
| F008-S | 24 | 3515.995 | 125.000 | -221.553 | 0.0 | 42.9 | FLY |
| F009-H | 24 | 3539.649 | 125.000 | -223.733 | 0.0 | 138.9 | FLY |
| F009-S | 24 | 3521.466 | 104.000 | -223.008 | 0.0 | 150.0 | FLY |
| F010-H | 24 | 3526.113 | 125.000 | -222.131 | 0.0 | 71.1 | FLY |
| F010-S | 24 | 3527.419 | 125.000 | -222.446 | 0.0 | 83.1 | FLY |
| F011-H | 24 | 3610.350 | 60.000 | -221.560 | 0.0 | 49.2 | no |
| F011-S | 24 | 3605.366 | 60.000 | -222.198 | 0.0 | 62.1 | no |
| F012-H | 24 | 3610.976 | 60.000 | -221.553 | 0.0 | 88.2 | no |
| F012-S | 24 | 3610.442 | 60.000 | -222.690 | 0.0 | 117.0 | no |
| F013-H | 24 | 3621.567 | 60.000 | -222.822 | 0.0 | 94.5 | no |
| F013-S | 24 | 3621.461 | 60.000 | -222.347 | 0.0 | 140.7 | no |
| F014-H | 24 | 3616.954 | 60.000 | -221.922 | 0.0 | 94.5 | no |
| F014-S | 24 | 3621.528 | 60.000 | -221.804 | 0.0 | 85.5 | no |
| F015-H | 24 | 3527.010 | 125.000 | -221.979 | 0.0 | 55.2 | FLY |
| F015-S | 24 | 3513.110 | 125.000 | -222.250 | 0.0 | 140.1 | FLY |
| F016-H | 24 | 3516.634 | 125.000 | -221.672 | 0.0 | 26.4 | FLY |
| F016-S | 24 | 3526.666 | 125.000 | -222.019 | 0.0 | 57.0 | FLY |
| F017-H | 24 | 3539.204 | 125.000 | -222.003 | 0.0 | 50.1 | FLY |
| F017-S | 24 | 3527.092 | 125.000 | -222.300 | 0.0 | 75.0 | FLY |
| F018-H | 24 | 3526.981 | 125.000 | -222.191 | 0.0 | 45.3 | FLY |
| F018-S | 24 | 3515.304 | 125.000 | -222.178 | 0.0 | 64.8 | FLY |
| F019-H | 24 | 3537.638 | 125.000 | -222.285 | 0.0 | 61.8 | FLY |
| F019-S | 24 | 3540.807 | 125.000 | -221.572 | 0.0 | 90.3 | FLY |
| F020-H | 24 | 3614.066 | 60.000 | -222.148 | 0.0 | 84.9 | no |
| F020-S | 24 | 3608.272 | 60.000 | -222.194 | 0.0 | 99.3 | no |
| F021-H | 24 | 3525.837 | 125.000 | -221.767 | 0.0 | 96.6 | FLY |
| F021-S | 24 | 3520.116 | 116.000 | -221.687 | 0.0 | 122.1 | FLY |
| F022-H | 24 | 3621.627 | 60.000 | -221.803 | 0.0 | 86.1 | no |
| F022-S | 24 | 3621.652 | 60.000 | -222.162 | 0.0 | 98.1 | no |
| F023-H | 24 | 3621.395 | 60.000 | -222.369 | 0.0 | 55.8 | no |
| F023-S | 24 | 3619.814 | 60.000 | -221.656 | 0.0 | 54.0 | no |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| F024-H | 24 | 3630.282 | 60.000 | -221.782 | 90.0 | 61.5 | m/b |
| F024-S | 24 | 3612.648 | 60.000 | -221.918 | 0.0 | 75.3 | no |
| F025-H | 24 | 3521.782 | 125.000 | -221.972 | 0.0 | 57.6 | FLY |
| F025-S | 24 | 3621.649 | 60.000 | -221.884 | 0.0 | 77.7 | no |
| F026-H | 24 | 3614.718 | 60.000 | -221.690 | 0.0 | 76.2 | no |
| F026-S | 24 | 3613.401 | 60.000 | -222.341 | 0.0 | 57.0 | no |
| F027-H | 24 | 3616.176 | 60.000 | -221.756 | 0.0 | 68.1 | no |
| F027-S | 24 | 3621.650 | 60.000 | -222.151 | 0.0 | 110.4 | no |
| F028-H | 24 | 3614.980 | 60.000 | -222.021 | 90.0 | 91.5 | m/b |
| F028-S | 24 | 3618.945 | 60.000 | -222.108 | 0.0 | 105.0 | no |
| F029-H | 24 | 3611.557 | 60.000 | -221.649 | 0.0 | 47.4 | no |
| F029-S | 24 | 3618.791 | 60.000 | -222.046 | 0.0 | 77.4 | no |
| F030-H | 24 | 3612.458 | 60.000 | -221.778 | 0.0 | 75.0 | no |
| F030-S | 24 | 3612.579 | 60.000 | -221.854 | 0.0 | 62.4 | no |
| F031-H | 24 | 3609.286 | 60.000 | -221.868 | 0.0 | 47.7 | no |
| F031-S | 24 | 3614.161 | 60.000 | -221.537 | 0.0 | 85.5 | no |
| F032-H | 24 | 3614.211 | 60.000 | -222.441 | 0.0 | 113.4 | no |
| F032-S | 24 | 3537.137 | 125.000 | -222.091 | 0.0 | 106.2 | FLY |
| F033-H | 24 | 3621.616 | 60.000 | -223.306 | 0.0 | 139.5 | no |
| F033-S | 24 | 3621.535 | 60.000 | -222.988 | 0.0 | 150.0 | no |
| F034-H | 24 | 3528.604 | 125.000 | -221.512 | 0.0 | 115.2 | FLY |
| F034-S | 24 | 3527.158 | 108.000 | -222.313 | 0.0 | 125.4 | FLY |
| F035-H | 24 | 3607.665 | 60.000 | -221.950 | 90.0 | 46.5 | m/b |
| F035-S | 24 | 3615.040 | 60.000 | -222.030 | 0.0 | 62.7 | no |
| F036-H | 24 | 3518.962 | 125.000 | -221.829 | 0.0 | 36.9 | FLY |
| F036-S | 24 | 3519.441 | 125.000 | -221.572 | 0.0 | 32.4 | FLY |
| F037-H | 24 | 3615.836 | 60.000 | -222.491 | 90.0 | 96.6 | m/b |
| F037-S | 24 | 3615.448 | 60.000 | -221.951 | 0.0 | 144.0 | no |
| F038-H | 24 | 3621.549 | 60.000 | -222.192 | 0.0 | 80.4 | no |
| F038-S | 24 | 3621.579 | 60.000 | -221.983 | 0.0 | 93.0 | no |
| F040-H | 24 | 3528.058 | 125.000 | -221.626 | 0.0 | 59.7 | FLY |
| F040-S | 24 | 3613.119 | 60.000 | -222.216 | 0.0 | 68.7 | no |
| F041-H | 24 | 3610.754 | 60.000 | -221.668 | 0.0 | 22.5 | no |
| F041-S | 24 | 3615.973 | 60.000 | -221.910 | 0.0 | 52.8 | no |
| F042-H | 24 | 3533.939 | 125.000 | -222.308 | 0.0 | 60.3 | FLY |
| F042-S | 24 | 3526.739 | 117.000 | -222.107 | 0.0 | 50.1 | FLY |
| F043-H | 24 | 3520.063 | 125.000 | -221.551 | 0.0 | 58.8 | FLY |
| F043-S | 24 | 3520.841 | 125.000 | -221.567 | 0.0 | 63.3 | FLY |
| H001-H | 24 | 3621.559 | 60.000 | -221.515 | 0.0 | 69.0 | no |
| H002-H | 24 | 3542.260 | 125.000 | -221.584 | 0.0 | 37.8 | FLY |
| H003-H | 24 | 3617.656 | 60.000 | -222.150 | 0.0 | 79.5 | no |
| I001-H | 24 | 3524.427 | 93.000 | -221.993 | 0.0 | 39.3 | FLY |
| I001-S | 24 | 3538.091 | 125.000 | -221.665 | 0.0 | 108.9 | FLY |
| P001-H | 24 | 3534.124 | 126.000 | -221.622 | 0.0 | 77.7 | FLY |
| P001-S | 24 | 3521.172 | 196.000 | -221.613 | 0.0 | 116.1 | FLY |
| P002-H | 24 | 3537.322 | 250.000 | -221.813 | 0.0 | 93.3 | FLY |
| P002-S | 24 | 3519.287 | 136.000 | -222.083 | 0.0 | 111.6 | FLY |
| P003-H | 24 | 3621.649 | 60.000 | -221.612 | 0.0 | 21.3 | no |
| P003-S | 24 | 3621.638 | 60.000 | -221.654 | 0.0 | 29.1 | no |
| P004-H | 24 | 3545.076 | 250.000 | -222.107 | 0.0 | 68.1 | FLY |
| P004-S | 24 | 3537.100 | 250.000 | -221.505 | 0.0 | 39.3 | FLY |
| P005-H | 24 | 3526.463 | 192.000 | -221.691 | 0.0 | 46.2 | FLY |
| P005-S | 24 | 3529.464 | 136.000 | -221.506 | 0.0 | 95.1 | FLY |
| P006-H | 24 | 3621.648 | 60.000 | -221.838 | 0.0 | 84.9 | no |
| P006-S | 24 | 3509.829 | 118.000 | -222.354 | 0.0 | 78.0 | FLY |
| P007-H | 24 | 3625.727 | 60.000 | -222.085 | 90.0 | 67.8 | m/b |
| P007-S | 24 | 3522.959 | 250.000 | -222.190 | 0.0 | 44.1 | FLY |
| P008-H | 24 | 3621.600 | 60.000 | -221.893 | 0.0 | 55.5 | no |
| P008-S | 24 | 3601.626 | 60.000 | -222.937 | 0.0 | 94.8 | no |
| P009-H | 24 | 3525.577 | 158.000 | -223.179 | 0.0 | 148.5 | FLY |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| P009-S | 24 | 3605.339 | 60.000 | -221.535 | 0.0 | 85.2 | no |
| P010-H | 24 | 3621.644 | 60.000 | -222.570 | 0.0 | 76.2 | no |
| P010-S | 24 | 3541.241 | 82.000 | -222.251 | 0.0 | 63.9 | FLY |

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