p-82

# THE EFFECTS OF OUTCOME AND PROCESS FEEDBACK ON PERFORMANCE

Technical Report

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## Abstract

A laboratory study was conducted to examine the effects of process and outcome feedback on performance during a skill acquisition phase and a transfer test phase. The research also examined the role of two moderators: self-efficacy and intrinsic motivation. Subjects were college students participating for course credit. The task involved using a computerized simulation of the Space Shuttle's Remote Manipulation System (RMS). Results provided evidence of the beneficial effects of process feedback during skill acquisition. Results also provided evidence that self-efficacy and intrinsic motivation moderate the effects of feedback type on performance.

# The Effects of Outcome and Process Feedback on Performance

The beneficial effects of feedback have been well documented. There is evidence that individuals prefer specific, timely feedback (e.g., Ilgen, Fisher, & Taylor, 1979; Liden & Mitchell, 1985). Moreover, specific, timely feedback has been found to enhance performance (e.g., Locke, Shaw, Latham, & Saari, 1981). However, the beneficial effects of feedback may depend on the type of feedback delivered and may be affected by other factors. For example, feedback type may influence its effectiveness. Different types of feedback such as outcome and process feedback may have differential effects on performance (Earley, Northcraft, Lee, & Lituchy, 1990). Further, the effects of feedback on performance may be moderated by other factors such as self-efficacy or intrinsic motivation. Indeed, research suggests that positive feedback (i.e., feedback sign) enhances performance through its effects on self-efficacy (Earley, 1986) and intrinsic motivation (Harackiewcz & Larson, 1986; Sansone, 1986). It is not clear, however, whether the effects of feedback type are similarly mediated by these factors or whether these factors perform a different function in the feedback type - performance relationship. A better understanding is needed of the mechanisms underlying the feedback process, especially in terms of feedback type and factors affecting feedback effects.

Different approaches have been taken to investigate feedback type. One approach has been to examine constructive (i.e., feedback that is specific, considerate, and does not attribute poor performance to internal causes) versus destructive feedback (Baron, 1988). Another approach has been to examine feedback type in terms of normative versus task feedback (Harackiewcz & Larson, 1986; Sansone, 1986). Normative feedback indicates performance in comparison to others, while task feedback indicates knowledge of results. Others have examined feedback provided on different, or multiple, performance dimensions, such as quality and quantity (Ilgen & Moore, 1987).

Finally, researchers have addressed feedback type in terms of outcome versus cognitive (or process) feedback. This approach to feedback type remains relatively unexplored and has implications for performance on complex or uncertain tasks. Outcome feedback refers to information about performance outcomes (Earley et al., 1990) or the accuracy of the response (Jacoby, Mazursky, Troutman, & Kuss, 1984). Cognitive feedback refers to information regarding what underlies this accuracy (Jacoby et al., 1984). Process feedback, a related term, refers to information about the process of performing a task (Earley et al., 1990).

Although outcome feedback (i.e., knowledge of results) is commonly used, there is evidence that it may not be beneficial in some task conditions, such as complex, uncertain tasks (e.g., Jacoby et al., 1984). Using a complex, decision making task, Jacoby et al. (1984) found that higher performance was obtained by those who ignored outcome feedback. They posited that feedback will be used by individuals when it has either explanatory or predictive value. Feedback that neither aids the individual in understanding the results of previous performance nor enables the prediction of future performance will be ignored. Thus, cognitive feedback, arising from Social Judgment Theory (e.g., Todd & Hammond, 1965), offers an alternative to outcome feedback that may be more useful in uncertain task environments. Moreover, information about relations in the task may be the critical component of cognitive feedback in uncertain tasks (Balzer, Doherty, & O'Connor, 1989).

One purpose of the current study was to further examine the effects of process and outcome feedback on performance. This replicates previous research by examining the effects of process versus outcome feedback in a complex, novel task. Moreover, the current study extends previous research by examining the effects of feedback type on performance both during skill acquisition and in a transfer test. Feedback can have several functions, including providing information and influencing motivation (Ilgen et al., 1979). Further, the information function has relatively permanent learning effects while the motivational function is more temporary, disappearing when feedback is withdrawn.

Studies of motor learning (e.g., Salmoni, Schmidt, & Walter, 1984) offer a method for examining the effects of feedback on motivation and learning. In these studies performance data is collected during an acquisition phase and a transfer phase to investigate whether a feedback intervention is influencing motivation and/or learning. Feedback is provided during the acquisition phase and withdrawn during the transfer phase. Performance during the acquisition phase is expected to be influenced by both the information and motivation functions of feedback. However, in the transfer phase, one would expect performance to remain high to the extent that the previously received feedback provides information which influences learning and decline to the extent that the feedback has a motivational function.

In the current study, the effects of feedback type are examined using a complex, novel task. Process and outcome feedback are expected to have similar effects on motivation. However, process feedback is expected to have greater informational value to the individual than outcome feedback. This would be beneficial to individuals both during the acquisition phase and the transfer phase and leads to the following predictions.

$H_1$: Process feedback will enhance performance more than outcome feedback during the acquisition phase.

$H_2$: Process feedback will enhance performance more than outcome feedback during the transfer phase.

A second purpose of the current study is to further explore factors which may moderate the effects of feedback on performance. Two potential moderators are examined: self-efficacy and intrinsic motivation. Self-efficacy is an assessment of an individual's confidence that s/he can demonstrate various levels of performance on a given task (Bandura & Cervone, 1983). Research has shown that individuals with higher self-efficacy demonstrate better performance (Bandura & Cervone, 1983). Moreover, those who receive positive feedback report higher self-efficacy than those who receive negative feedback (Earley, 1986). Moreover, there is some evidence that feedback sign (positive versus negative) affects performance through its effects on self-efficacy (Bandura & Cervone, 1983; Earley, 1986) although others have not obtained support for self-efficacy as a mediator (Podsakoff & Fahr, 1989). Thus, research suggests that self-efficacy may mediate the effects of feedback sign on performance.

However, it is not clear that self-efficacy will have the same function in the feedback type - performance relationship. The current study extends previous research by assessing whether self-efficacy influences the effect of feedback type on performance. To the extent that process feedback provides individuals with information they can use to improve their performance, process feedback could result in higher levels of self-efficacy than outcome feedback and, in turn, lead to higher performance. However, it could also be argued that due to the additional information content of process feedback, increases in self-efficacy play a less important role in improving performance. That is, the informational content alone of process feedback may lead to increases in performance. This is consistent with previous research (e.g., Jacoby et al., 1984) suggesting process feedback will be more valued and attended to because it provides the information needed to improve performance on complex or uncertain tasks. On the other hand, self-efficacy may play a more important role in performance improvement in the outcome feedback condition due to the lack of informational content in the feedback. Indeed, indirect evidence of this is offered by Earley et al. (1990) using a related concept, self-confidence. They found that individuals with specific (versus general) goals and specific (versus general) outcome feedback had higher self-rated effort and self-confidence, but no relationship was found between process feedback and self-confidence. Thus, research suggests that higher self-efficacy will be associated with higher performance but that the strength of these effects may depend on the type of feedback provided. That is, self-efficacy may compensate for the low information in outcome feedback.

$H_3$: Self-efficacy moderates the effect of feedback type on performance.

$H_3a$: Self-efficacy is positively related to performance in the outcome feedback condition but not in the process feedback condition.

Similarly, the current study examines whether intrinsic motivation affects the feedback - performance relationship. Intrinsic motivation is posited to increase following positive feedback and decrease following negative feedback (Harackiewcz & Larson, 1986). Moreover, the competence information feedback conveys is considered a critical component. That is, competence information is posited to influence perceived competence which in turn influences intrinsic motivation (Sansone, 1986). Competence information is usually provided using normative feedback (social comparison information). Task feedback (i.e., knowledge of results) is expected to have a smaller impact on intrinsic motivation because it focuses the individual's attention on the task itself rather than on perceived competence (Sansone, 1986). Sansone's results support this in that individuals receiving normative feedback reported the highest perceived competence. However, task feedback also resulted in higher perceived competence, compared to those receiving no feedback.

Research has shown that competence information in feedback enhances intrinsic motivation (Harackiewicz & Larson, 1986). There is also evidence that positive feedback results in increased perceived competence (Stone & Stone, 1985). Moreover, researchers have suggested that feedback sign influences performance through its effects on intrinsic motivation (Harackiewcz & Larson, 1986; Sansone, 1986).

The current study extends previous research by examining the role of intrinsic motivation in the feedback type - performance relationship. Similar to self-efficacy, it is not clear that intrinsic motivation mediates the relationship. Rather, intrinsic motivation may interact with feedback type in its effects on performance. That is, intrinsic motivation is expected to play a less important role in performance improvements in the process feedback condition due to the high informational value of the feedback. However, intrinsic motivation is expected to play a more important role in the outcome feedback condition, compensating for the lack of information in the feedback.

$H_4$: Feedback type influences perceived competence.

$H_5$: Intrinsic motivation moderates the effect of feedback type on performance.

$H_5$a: Intrinsic motivation is positively related to performance in the outcome feedback condition but not in the process condition.

In addition, the relationship between feedback sign, intrinsic motivation, and performance has usually been studied using achievement oriented tasks where attaining competence is a primary goal. If competence is not a primary goal of task performance, then competence information may not enhance intrinsic motivation (Sansone, 1986). However, there is evidence that competence information may still enhance intrinsic motivation in certain non-achievement task situations. Specifically, researchers (Harackiewicz & Larson, 1986; Sansone, 1986) suggest that normative feedback can affect competence valuation which in turn influences intrinsic motivation. Competence valuation is the importance one places on doing well at an activity. However, unlike feedback sign, feedback type may interact with competence valuation in its effects on performance. Thus, it is expected that competence valuation will play a less important role in the process feedback condition and a more important role in the outcome feedback condition due the informational value of each condition.

$H_6$: Competence valuation moderates the effect of feedback type on intrinsic motivation.

$H_6a$: Competence valuation is positively related to intrinsic motivation in the outcome feedback condition but not in the process condition.

Finally, the effects of feedback type are expected to be moderated by individual difference factors such as self-esteem and need for achievement. There is evidence that feedback sign has differential effects on performance depending on self-esteem (Brockner, Derr, & Laing, 1987). High self-esteem individuals remain more motivated following negative feedback than low self-esteem individuals. There is also evidence that self-esteem affects perceived competence (Stone & Stone, 1985). A possibly related factor is self-confidence. Indeed, there is some evidence that sex differences exist in self-confidence levels following negative feedback (McCarty, 1986). Similarly, self-esteem and feedback type may jointly affect self-efficacy. Specifically, self-esteem is expected to influence self-efficacy in the outcome feedback condition but not in the process feedback condition. That is, higher self-esteem is likely to associated with higher self-efficacy. As before, this is due to the informational value of process feedback. When process information is available, individual difference factors are expected to play a smaller role in feedback effects.

$H_7$: Feedback type and self-esteem interact in their effects on self-efficacy.

$H_7a$: Self-esteem is positively related to self-efficacy in the outcome feedback condition but not in the process feedback condition.

Similarly, need for achievement and feedback type may jointly affect intrinsic motivation. There is evidence that need for achievement may moderate the effect of feedback sign on intrinsic motivation in that high need for achievement individuals are more sensitive and responsive to feedback sign (Matsui, Okada, & Inoshita, 1983; Matsui, Okada, & Kakuyama, 1982; Sansone, 1986). It is plausible that need for achievement would also differentially affect intrinsic motivation, depending on feedback type. That is, need for achievement may play a stronger role in the outcome feedback condition, due to its low informational value, and play a weaker role in the process condition. That is, higher need for achievement is likely to associated with higher intrinsic motivation in the outcome but not the process feedback condition.

$H_8$: Feedback type and need for achievement interact in their effects on intrinsic motivation.

$H_8a$: Need for achievement is positively related to intrinsic motivation in the outcome feedback condition but not in the process condition.

## Method

A computerized simulation of the Space Shuttle's Remote Manipulation System (RMS) was used to examine the effects of feedback on performance during the acquisition phase and on a transfer test.

### Subjects

Sixty undergraduate students from a large southwestern university participated in a 3-hour experimental session in exchange for bonus points that could be applied to their psychology course grade and five dollars ($5.00) to cover travel expenses. (The data collection was conducted off-campus.) Six subjects were excluded from the study. Two subjects were removed from the outcome feedback condition because of missing data due to computer simulation malfunctions. Four subjects were removed from the process feedback condition: one subject because of missing data due to a computer simulation malfunction and three subjects for failure to follow task instructions. The final sample included 54 subjects. Twenty-seven subjects participated in the process feedback condition (11 males; 16 females), and 27 participated in the outcome feedback condition (12 males; 15 females).

Subjects were randomly assigned to a feedback condition (outcome or process). All subjects performed six task trials (lasting a maximum of 10 minutes each). Cycle 1 was a practice cycle and was used to examine potential initial group differences and to enable the provision of feedback.

Task Overview

A computerized task simulation of the Space Shuttle's Remote Manipulation System (RMS) has been developed for use in training astronauts and payload specialists. The RMS is a robotic arm that is used to deploy and/or stow shuttle payloads (e.g., satellites). The task simulates some of the activities performed by a shuttle RMS operator. Task activities are directed toward retrieving (i.e., grappling) a payload in space and stowing it safely in the shuttle's payload bay. This requires starting the system, moving the RMS to a few inches away from the payload, grappling the payload, moving the RMS with the payload attached to it, stowing the payload, detaching the RMS from the payload, and moving the RMS away from the payload. To perform this task also requires manipulating cameras to obtain better views of the RMS, payload, and payload bay. To perform the task, subjects use hand controls, the keyboard, and a control box to manipulate task components viewed on a computer monitor.

Subjects are seated in a specially designed chair with hand controls on the end of each chair arm. Subjects use both controls to maneuver the RMS. The left hand control is the translator, a handle laying parallel to the chair arm. The translator moves the RMS on the X, Y, and Z axes which represent the length, width, and height of the shuttle, respectively (see Figure 1). Pushing the translator in moves the RMS forward on the X axis; pulling moves the RMS backward. Moving the translator left and right moves the RMS on the Y axis. Moving the translator up and down moves the RMS on the Z axis.

The right hand control is a joystick which enables subjects to change pitch, yaw, or roll. The joystick rotates the end effector (the tip of the RMS). Moving the joystick up or down changes the pitch (rotation about the Y axis). Moving the joystick left and right changes roll (rotation about the X axis). Finally, twisting the joystick clockwise and counterclockwise changes the yaw (rotation about the Z axis). The joystick also contains a trigger that is pulled to grapple the payload after engaging in End Effector Mode Auto. Further, a black button at the top left of the joystick control box is used in the task to disengage the RMS from the payload.

Subjects view a monitor that contains four windows. The lower left hand window contains the control panel. The control panel contains simulated dials, including the Mode, Parameter, and Joint dials. Information about the RMS such as the current mode, whether the RMS is attached to the payload, and parameters (such as the position of the RMS relative to the nose of the shuttle) is found on the control panel. The other three windows contain views from cameras that are either attached to the RMS or are on the shuttle. The name of the camera appearing in the window is located at the top of the window. The location of each camera on the shuttle is shown in Figure 2.

To the right of the computer monitor is a control box. A diagram of the control box is found in Figure 3. The control box contains buttons and dials that control RMS operations and camera movement/selection. The control box buttons were used to control camera movement and selection. The control box also contained a button called End Effector Auto (EE Mode Auto). This button was pressed before pulling the trigger in the joystick. It automatically connects and latches the RMS to the payload. Another button, the Enter button, was used to activate the selection made using the Mode dial described below. Other buttons were available but were not used in the current study.

Three dials on the control box were used to control the Mode, Parameter selection, and Joint Angle selection. Turning these dials moves the corresponding dial located on the control panel on the monitor display. For the purposes of this project, the subjects could only engage in End Effector Mode using the Mode Dial. In addition, they were only allowed to select Position X/Y/Z, or Joint Angle on the Parameter Dial. On the Joint Dial, only the Wrist, Elbow, or Shoulder angles could be chosen for viewing. Other information settings were available on the Mode, Parameter, and Joint Dials, but subjects were restricted from using them in the current study to simplify the task situation.

Six cameras were available in the simulation: A, B, C, D, Wrist, and Elbow. With the exception of the wrist camera, the cameras could tilt, pan, or zoom to obtain a desired view. Although the wrist camera could be adjusted on the simulation, subjects were restricted from doing this because the wrist camera is not adjustable on the actual shuttle.

A computer mouse was located in the work area in front of the control box. The mouse was used to activate windows so that the camera in that window could be adjusted or changed. A small red arrow in a window indicated the window was active. To select a window, subjects used the mouse to move the arrow to the desired window.

Twenty-seven rules governed task performance (see Appendix A). These rules identified incorrect actions. They were available for subjects to review throughout task performance. When subjects performed an action that violated a rule, the error was recorded by the experimenter. Subjects were not informed about errors they made until the end of each task cycle.

Subjects received feedback following each of the first four task cycles. No feedback was provided following Cycles 5 and 6. Cycles 1 through 5 constituted the acquisition phase and Cycle 6 provided the transfer test. The type of feedback provided depended on the feedback condition to which the subject was assigned. Subjects in the process feedback condition received process feedback following Cycles 1 through 4; similarly, those in the outcome feedback condition received outcome feedback for Cycles 1 through 4. The same performance rules were in effect for all subjects in all cycles.

## Feedback Manipulation

Subjects were randomly assigned to one of two experimental conditions: outcome feedback or process feedback. Subjects in the outcome feedback condition were told: "You made ____ different types of errors. You may wish to review the performance rules before performing the next cycle." Subjects were then provided with a list of the performance rules (see Appendix A for rules). Subjects were not told which performance rules they had violated.

Subjects in the process feedback condition were told: "You made ____ different types of errors." The experimenter then read a specific feedback message for each type of error made (see Appendix B). These messages included a restatement of the performance rule and a suggestion for avoiding the error in the future. Subjects were not allowed to read the full feedback message list. However, the task instructions given prior to task performance indicated that subjects could review the task performance rules at any time during task performance.

All subjects were provided with feedback after the first four cycles. No feedback was provided following Cycles 5 or 6. This procedure enabled us to use Cycle 6 as a no feedback transfer test (Salmoni et al., 1984). Cycles 1 through 5 constituted an acquisition phase.

## Measures

General Cognitive Ability. General cognitive ability was assessed using the Wonderlic Personnel Test (Wonderlic, 1983). The Wonderlic is a 50-item, 12-minute timed test. Ability was used as a covariate in some analyses.

Spatial Relations. The Space Relations section of the Differential Aptitude Test - Form V (DAT) was administered to measure spatial relations (Bennett, Seashore, & Wesman, 1982). This 60-item, 25-minute timed test assesses the ability to deal with concrete materials through visualization. Each item shows a pattern for a three dimensional figure. Subjects select the assembled figure that can be made from the pattern shown. Ability was used as a covariate in some analyses.

Need for Achievement. The Work and Family Orientation (WOFO) Scale was used to assess need for achievement (Helmreich & Spence, 1978). This scale assesses four components of achievement motivation: need for mastery, need for work, competitiveness, and personal unconcern. The Need for Mastery scale contains eight items; Need for Work consists of six items; Competitiveness contains five items; and Personal Unconcern contains four items. Helmreich and Spence report scale reliabilities (Cronbach's alpha) of .61 for Mastery, .66 for Work, .76 for Competitiveness, and .50 for Personal Unconcern based on a sample of 607 male college students. Reliabilities were recalculated for the current study using the 54 subjects. Similar reliabilities were obtained: Cronbach's alpha = .70 for Mastery, .70 for Work, .65 for Competitiveness, and .32 for Personal Unconcern. However, because the task had no opportunity for competition with others, the Competitiveness scale was not used in the analyses. Further, the Personal Unconcern scale was not used due to the low scale reliabilities reported by Helmreich & Spence (1978) and obtained in the current study.

Self Esteem. The Coopersmith Self Esteem Inventory (Coopersmith, 1967) was used to measure self-esteem. The scale contains 25 items. Respondents indicate whether each statement describes them ("like me" or "unlike me"). The scale reliability obtained in the current study was alpha = .74.

Self-Efficacy. Self-Efficacy was assessed prior to Cycles 1, 2, 3, 4, and 5. Subjects reported their confidence (i.e., [1] no confidence to [10] total confidence) that they could grapple and correctly stow the payload with varying numbers of errors (see Appendix C). This variable was labelled Task-Specific Self-Efficacy in the analyses. A second, more general measure of self-efficacy (labelled General Self-Efficacy) was also obtained for the same cycles. Subjects reported their confidence (i.e., [1] no confidence to [10] total confidence) that they could grapple the payload regardless of the number of errors. Responses obtained prior to Cycle 1 were used to assess potential initial group differences. Responses obtained prior to Cycles 2 and 5 were used in tests of hypotheses.

Intrinsic Motivation. Seven items were used to assess intrinsic motivation (item numbers 1, 4, 10, 13, 14, 17, and 19 in Appendix D). The items required responses on 7-point Likert scales (e.g., [1] strongly disagree to [7] strongly agree). Items 1 and 10 were reverse scored. The reliability was alpha = .90. Responses were obtained on completion of Cycle 6.

Perceived Competence. Three items were used to assess perceived self-competence (item number 8, 16, and 21 in Appendix D). The items required responses on responses on 7-point Likert scales (e.g., [1] strongly disagree to [7] strongly agree). Items 8 and 16 were reverse scored. The scale reliability was alpha = .89. Responses were obtained following Cycle 6.

Competence Valuation. The extent to which competence was valued was assessed using two items (item numbers 7 and 11 in Appendix D). Item responses were made on a 7-point Likert scale ([1] strongly disagree to [7] strongly agree). The scale reliability was alpha = .67. Responses were obtained upon completion of Cycle 6.

Performance Measures. Four measures of task performance were obtained for each cycle: distance from grapple, number of errors, number of error types, and grapple success. **Distance from Grapple** referred to the distance between the end effector and the grapple fixture. The X, Y, and Z coordinates for the end effector were recorded at the end of each cycle. These values and the grapple fixture coordinates were used to calculate the distance score. If the subject grappled the payload, the distance score was zero. **Number of Errors** referred to the total number of errors made, including multiple occurrences of any given error type, during each task cycle. **Number of Error Types** referred to the number of different types of errors made during each task cycle. There were 27 types of errors possible. **Grapple Success** referred to whether the subject successfully grappled the payload (0 = No; 1 = Yes).

Post hoc analyses were also conducted on five specific types of errors: singularity (#1), contact with payload (#9), EE auto mode engagement (#10), backing up (#16), and control box error (#19).

Procedure

Following a brief introduction to the session and agreeing to participate (see Appendix E), subjects completed questionnaires addressing general cognitive ability, spatial relations, need for achievement, and self-esteem. Subjects were then seated at an individual RMS workstation. They were given written task instructions (see Appendix F) explaining the mechanics of and rules governing task performance. They were also given five templates (see Appendix G) summarizing how to perform key activities described in the task instructions. Following the instructions and templates, the experimenter gave the following additional instructions to ensure subjects understood the task:

> "In sum, you are to take the RMS here (experimenter pointed to the tip of the RMS on the computer monitor), move it to within a few inches away from the flat surface of the gray octagon (experimenter pointed to the location), grapple the aqua colored payload, and then move the payload

into the payload bay (experimenter pointed to the location). We recommend that you use the translator when moving the RMS. Remember the translator moves the RMS forward and back on the X axis, side to side on the Y axis, and up and down on the Z axis. Only use the joystick when making minor alignments and adjustments. We also recommend that you move and/or adjust cameras as you feel necessary."

Subjects then completed a self-efficacy questionnaire and began performing the six task cycles. Feedback was provided immediately following each of the first 4 cycles. In addition, subjects completed a self-efficacy questionnaire prior to performing Cycles 2, 3, 4, and 5. Finally, subjects reported intrinsic motivation, perceived competence, and competence valuation following Cycle 6. Demographic information was also obtained following Cycle 6. Subjects were then debriefed, given course credit slips, paid, and dismissed.

## Results

### Potential Initial Group Differences

One-way ANOVA's with spatial relations used as a covariate were conducted to examine potential initial group differences in three performance measures: Distance from Grapple, Number of Errors, and Number of Error Types. The results indicated an effect for the covariate on Distance from Grapple ($F(1, 51) = 4.55$, $p < .05$) but no effects for feedback condition on any of the three performance measures. Subjects in the outcome feedback condition attained a similar distance from grapple ($M = 74.55$, $SD = 93.49$) as those in the process feedback condition ($M = 64.71$, $SD = 114.46$). Subjects also made similar numbers of errors in the outcome ($M = 6.30$, $SD = 6.02$) and process ($M = 6.26$, $SD = 4.55$) conditions. Finally, subjects made similar numbers of different types of errors in the outcome ($M$ = 2.78, $SD$ = 1.69) and process ($M$ = 3.07, $SD$ = 1.75) conditions. Similar results were obtained using general cognitive ability and sex as covariates. No differences between feedback conditions were obtained in Cycle 1.

Correlations among the performance measures were also calculated, revealing a significant correlation only between Number of Errors and Number of Error Types ($r$ = .81, $p$ < .01). For completeness, analyses examining the effects of feedback type on performance were run separately for Number of Errors and Number of Error Types. However, because of the similarity of results obtained further analyses were conducted only on Number of Errors.

A Chi-square test was also conducted to examine potential initial group differences on Grapple Success. The results indicated no difference between feedback conditions ($\chi^2(1, 53) = 0.35$, n.s.). Only one subject in the outcome feedback condition ($n$ = 27) successfully grappled the payload in Cycle 1, compared with two subjects in the process feedback condition ($n$ = 27).

One-way ANOVA's were also conducted to examine potential initial group differences in individual difference factors and self-efficacy at Cycle 1. The results indicated no differences between feedback condition for any factor, except for need for mastery ($F(1, 52) = 5.00$, $p$ < .05). Subjects in the outcome feedback condition exhibited lower need for mastery scores ($M$ = 11.00, $SD$ = 4.53), compared to those in the process feedback condition ($M$ = 13.85, $SD$ = 4.83). Need for mastery was omitted from further analyses.

However, no differences were obtained for the other factors. Subjects demonstrated similar levels of general cognitive ability in the outcome ($M$ = 25.89, $SD$ = 4.60) and process ($M$ = 24.92, $SD$ = 5.98) feedback conditions and similar levels of spatial relations ability in the outcome (*M* = 38.81, *SD* = 8.58) and process (*M* = 41.00, *SD* = 11.95) conditions. Subjects also displayed similar levels of need for work (outcome *M* = 2.07, *SD* = 2.23; process *M* = 2.04, *SD* = 2.64), self esteem (outcome *M* = 18.52, *SD* = 3.72; process *M* = 17.96, *SD* = 4.30), and Cycle 1 self-efficacy (outcome *M* = 22.67, *SD* = 15.56; process *M* = 24.73, *SD* = 14.53).

## Effect of Feedback Condition on Performance in the Acquisition Phase

A 2 X 4 repeated measures ANOVA with Cycle 1 performance used as a covariate was conducted to examine the effects of feedback condition on performance in the acquisition phase. Process feedback was expected to result in better performance, compared to outcome feedback across Cycles 2 through 5 for each performance measure.

The results supported this prediction for Number of Errors and Number of Error Types. Results of the analyses revealed a significant effect for feedback condition on both Number of Errors and Number of Error Types (see Table 1). For both performance measures subjects in the Process feedback condition performed better, compared to those in the Outcome feedback condition. That is, subjects in the Process feedback condition demonstrated a smaller total number of errors and fewer different types of errors (see Table 2). (Note: Table 2 also includes means and standard deviations from Cycle 6, the transfer test cycle.) In addition, the results indicated a significant Cycle X Feedback interaction effect on Number of Errors. As shown in Table 2, those in the Process feedback condition demonstrated a decrease in the number of errors by Cycle 5 while those in the Outcome feedback condition demonstrated an increase in the number of errors by Cycle 5.

No effect for feedback was obtained on Distance from Grapple. In addition, the assumptions of the covariance analysis were violated by a significant Cycle X Cycle 1 Covariate interaction effect. So, the analysis was repeated, entering Cycle 1 performance as a factor rather than as a covariate. The results again revealed no effect for feedback.

Further, $\chi^2$ tests on Grapple Success revealed an effect for feedback condition but not in the direction predicted. That is, results of the $\chi^2$ tests indicated a significant effect for feedback condition in Cycle 2 (see Table 3). (Note: Table 3 also includes frequencies and percentages for Cycle 6, the transfer test cycle.) Four subjects in the outcome feedback condition successfully grappled the payload in Cycle 2, compared with no subjects in the process feedback condition. No differences between feedback conditions were obtained in Cycles 3 through 5.

Effect of Feedback Condition on Specific Error Types in the Acquisition Phase. Follow-up analyses were conducted to further examine the feedback effects found in the acquisition phase. Specifically, a 2 X 4 repeated measures ANOVA with Cycle 1 performance used as a covariate was conducted to examine the effects of feedback condition on each of the five most frequently occurring errors. The five errors were Singularity, Touching Payload, EE Engagement Distance, Backing Up, and EE Mode Button Errors (see Appendix A for rule statements). These errors were selected because at least one subject made this error three or more times in every task cycle. Means and standard deviations for these variables are shown in Table 4. Intercorrelations among these variables are shown in Table 5.

Results of these analyses revealed a significant effect for feedback condition only for Backing Up (see Table 6). Subjects in the Outcome feedback condition backed up more frequently, compared to those in the Process feedback condition (see Table 4).

Effect of Feedback Condition on Performance in the Transfer Test

A one-way ANOVA with the average of Cycles 2 through 5 performance used as a covariate was conducted to examine the effects of feedback condition on performance in the transfer test, Cycle 6. Process feedback was again expected to result in better performance, compared to outcome feedback. However, no effects for feedback were obtained on Distance from Grapple, Number of Errors, or Number of Error Types (see Table 7). Subjects performed at similar levels in each feedback condition (see Table 2).

Similarly, results of a $\chi^2$ test on Grapple Success did not reveal an effect for feedback condition. Similar numbers of subjects successfully grappled the payload in Cycle 6 across feedback conditions.

Effects of Feedback Condition and Self-Efficacy on Performance

Hierarchical multiple regression analyses were conducted to assess whether self-efficacy moderates the feedback type - performance relationship at either Cycle 2 or Cycle 5. The analyses were first conducted using the Task-Specific Self-Efficacy (i.e., summing confidence ratings across performance levels). A Cycle 1 performance covariate (number of errors), feedback type, and self-efficacy were entered into the equation first (Model 1). The Feedback Type X Self-Efficacy interaction effect was entered in the second step (Model 2, the full model). At Cycle 2, Model 1 and Model 2 were both significant, indicating significant effects for the covariate in both models and feedback type in the full model (see Table 8). However, the Feedback Type X Self-Efficacy interaction effect did not result in a significant increment in variance when it was added in the full model. Similarly, at Cycle 5, both Models 1 and 2 were significant, revealing significant effects for feedback type. However, the addition of the Feedback Type X Self-Efficacy interaction effect did not result in a significant increment in variance in the full model. Thus, there was no evidence that task-specific self-efficacy moderates the feedback type - performance relationship. This may have resulted from the fact that this measure assessed confidence that subjects could grapple and stow the payload with varying numbers of errors. However, no subjects in the current sample were able to stow the payload, influencing the effectiveness of this self-efficacy measure.

The analyses were then conducted using General Self-Efficacy. A Cycle 1 performance covariate (number of errors), feedback type, and self-efficacy were entered into the equation first (Model 1). The Feedback Type X Self-Efficacy interaction effect was entered in the second step (Model 2, the full model). Both models were significant, revealing significant effects for the covariate in Model 1 and the covariate and feedback type in Model 2. However, the addition of the Feedback Type X Self-Efficacy interaction term did not result in a significant increment in variance (see Table 9). Thus, no evidence was obtained indicating that self-efficacy moderates the feedback type - performance relationship at Cycle 2.

At Cycle 5, both models were again significant. Feedback type was the only significant effect revealed in Model 1. The full model revealed significant effects for feedback type, self-efficacy, and the Feedback Type X

Self-Efficacy interaction effect. Moreover, the addition of the interaction term resulted in a significant increment in variance for the full model. Thus, this analysis provides support for the hypothesis that self-efficacy moderates the feedback type - performance relationship.

To further examine the Feedback Type X Self-Efficacy interaction effect, a post hoc analysis was conducted, regressing performance on the covariate and self-efficacy within each feedback condition. The results indicated that self-efficacy is positively related to number of errors in the process condition (Beta = .30, $t$ = 1.81, $p$ < .10), indicating poorer performance, and negatively related to errors in the outcome feedback condition (Beta = -.36, $t$ = -1.92, $p$ < .10), indicating better performance. (Note: The $p$ level for significance was set at .10 for the follow-up tests to increase the power for detecting effects given the small sample size within feedback conditions.) Hence, higher self-efficacy levels were associated with better performance in the outcome condition but with worse performance in the process feedback condition, as predicted.

Effects of Feedback Condition and Intrinsic Motivation on Performance

Two tests were conducted. First, the effects of feedback type on perceived competence was assessed using a one-way ANOVA. Feedback sign has been shown to influence perceived competence and, in turn, intrinsic motivation. Thus, it was of interest to examine whether feedback type similarly has an effect on perceived competence. Results indicated no effect for feedback type ($F(1, 52)$ = .16, $p$ > .05) on perceived competence.

Second, hierarchical multiple regression analyses were conducted to assess whether intrinsic motivation moderates the feedback type - performance relationship at either Cycle 2 or Cycle 5. At Cycle 2, a Cycle 1 performance covariate, feedback type, and intrinsic motivation were entered first (Model 1). The Feedback Type X Intrinsic Motivation interaction effect was entered in the second step (Model 2; full model). The results indicated that both models were significant, revealing significant effects for the covariate in Model 1 and for the covariate and feedback type in the full model (see Table 10). Moreover, the addition of the interaction term in the full model resulted in a significant increment in variance accounted for. (Note: The entry of the interaction term may have played the role of a suppressor, increasing the Beta weights for feedback condition and intrinsic motivation by partialling out variance related to the interaction term but unrelated to the dependent variable.)

Post hoc follow-up tests were conducted within each feedback condition at Cycle 2, regressing performance on the covariate and intrinsic motivation. The results revealed that intrinsic motivation was not related to number of errors in the process feedback condition (Beta = .17, $t$ = .88, $p > .10$) but was negatively related to errors in the outcome feedback condition (Beta = -.30, $t$ = -1.81, $p < .10$), indicating better performance. (Note: The $p$ level for significance was set at .10 for the follow-up tests due to the small sample size within feedback conditions.) Thus, higher intrinsic motivation is associated with better performance (i.e., fewer errors) in the outcome feedback condition.

The same analyses were conducted at Cycle 5. The results indicated that both models were significant. They revealed a significant effect for feedback type in Model 1. Significant effects for feedback type, intrinsic motivation, and the Feedback Type X Intrinsic Motivation interaction effect were revealed in Model. Moreover, the addition of the interaction effect in the full model accounted for a significant increment in variance. (Note: The entry of the interaction term may have again played the role of a suppressor variable.)

Post hoc analyses, conducted within feedback conditions at Cycle 5, again revealed that intrinsic motivation was not related to number of errors in the process feedback condition (Beta = .10, $t = .59$, $p > .10$) but was negatively related to errors in the outcome feedback condition (Beta = -.36, $t = -1.91$, $p < .10$), indicating better performance. As before, higher intrinsic motivation is associated with better performance (i.e., fewer errors) in the outcome feedback condition.

Role of Competence Valuation in Feedback Type - Intrinsic Motivation Relationship

A hierarchical multiple regression analysis was conducted to assess whether competence valuation moderates the feedback type - intrinsic motivation relationship. Feedback type and competence valuation were entered first (Model 1). The Feedback Type X Competence Valuation interaction effect was entered in the second step (Model 2; full model). Model 1 was significant, indicating a significant effect for competence valuation (see Table 11). Higher competence valuation was associated with higher intrinsic motivation. However, Model 2 was not significant. The addition of the Feedback Type X Competence Valuation interaction term did not increment the variance accounted for.

Role of Individual Difference Factors in Feedback Type Effects on Self-Efficacy and Intrinsic Motivation

Two analyses were conducted to examine the role of individual difference factors in feedback effects. First, a hierarchical multiple regression analysis was conducted to examine whether feedback type and self-esteem interact in their effect on self-efficacy. This analysis was conducted on Cycle 5 General Self-Efficacy. The results indicated that neither model was significant. There was no evidence that feedback type, self-esteem or the Feedback Type X Self-Esteem interaction effect influenced Self-Efficacy.

Second, a hierarchical multiple regression analysis was conducted to examine whether feedback type and need for achievement (i.e., need for work) interact in their effects on intrinsic motivation. Here again, neither model was significant. There was no evidence that feedback type, need for work, or the Feedback Type X Need for Work interaction effect influenced Intrinsic Motivation.

## Discussion

The results provided support for Hypothesis 1 but not Hypothesis 2. The results revealed that those in the process feedback condition demonstrated fewer errors and fewer different types of errors, compared to those in the outcome feedback condition. Moreover, the results indicated that while those in the process feedback condition demonstrated a decreasing number of errors from Cycle 2 to Cycle 5, those in the outcome feedback condition demonstrated an increasing number of errors. Thus, the beneficial effect of process feedback was observed in terms of the number of errors subjects made during the acquisition phase.

Although the same result was expected during the transfer test cycle (Cycle 6), there was no evidence that feedback type differentially affected performance on Cycle 6. One possible explanation for this result is that the transfer test consisted of only one cycle. Typically, multiple cycles or trials are used in transfer tests. However, multiple transfer test cycles were not feasible in the current study due to time limitations and machine availability. Future research should examine the longer term effects of process and outcome feedback on performance during a transfer test using multiple cycles. Moreover, the same task was used in the transfer test as was used in the acquisition phase. Future research should also examine the effects of feedback type using a transfer test with a modified task version.

The research results also provided support for Hypothesis 3, indicating that self-efficacy moderates the feedback type - performance relationship. The results revealed that a significant increment in variance was accounted for by the interaction of self-efficacy and feedback type in their effects on performance at Cycle 5. The prediction was that self-efficacy would be positively related to performance in the outcome feedback condition but have little relationship to performance in the process feedback condition. Indeed, the results showed that higher self-efficacy was associated with better performance (i.e., fewer errors) in the outcome feedback condition.

However, the results also revealed that higher self-efficacy was associated with poorer performance (i.e., more errors) in the process condition which was not predicted. Self-efficacy was not expected to be related to performance in the process feedback condition due to its high informational content. One possible explanation for this result is that subjects in the process feedback condition who had higher self-efficacy made more errors because they increased their activity level. Unfortunately, no measure of activity level was available. However, if there was an increased activity level, it was not associated with improved performance in terms of successfully grappling the payload. That is, number of errors was not significantly correlated with success in grappling the payload. An alternate explanation may be that subjects with higher self-efficacy in the process feedback condition became overconfident and made more errors. The high informational value may have given high self-efficacy subjects an unrealistically high assessment of their capabilities and led them to make more errors. However, further research is needed to directly test this explanation. Research is also needed to determine whether these results generalize to other tasks and situations.

One other interesting aspect of the results relating to Hypothesis 3 is that they were obtained only for the more general measure of self-efficacy. The more commonly used task-specific measure of self-efficacy was not related to performance. This seems inconsistent with previous research demonstrating the robust relationship of self-efficacy to performance (e.g., Bandura & Cervone, 1983). However, this result highlights the importance of the design of self-efficacy measures. As noted above, the task-specific self-efficacy measure assessed subjects' confidence that they could <u>grapple</u> and <u>stow</u> the payload. However, while subjects were able to grapple payloads, no subjects in the current study were able to stow a payload in any cycle (with each cycle lasting a maximum length of 10 minutes). Pilot data indicated higher levels of success in stowing payloads. However, it was only possible to collect data from a few (less than 10) pilot subjects due to limitations of time and machine availability, and these pilot subjects may have performed at a higher level than that observed in the full study. Thus, in the current study, self-efficacy levels were uniformly low for the task-specific self-efficacy measure and unrelated to performance. On the other hand, the general self-efficacy measure assessed subjects' confidence that they could grapple a payload regardless of the number of errors. Thus, for the current study, the general self-efficacy measure was more appropriate for assessing self-efficacy - performance relationships and was found to be related to performance.

In summary, the results do provide support for Hypothesis 3 using the general self-efficacy measure. However, additional research using task-specific self-efficacy measures is needed to more systematically examine whether self-efficacy moderates the feedback type - performance.

With respect to the role of intrinsic motivation in the feedback type - performance relationship, the results provided evidence for Hypothesis 5 but not Hypothesis 4. No evidence was obtained indicating that feedback type influences perceived competence. This appears inconsistent with previous research suggesting that feedback sign (i.e., positive versus negative) differentially affects perceived competence (e.g., Harackiewcz & Larson, 1986; Sansone, 1986). However, feedback type appears to function rather differently than feedback sign. Indeed, the veridical (true) feedback provided in both feedback conditions ensured that some subjects perceived they had received positive feedback while others perceived the feedback they received was negative. Moreover, given that the task assigned was to grapple and stow the payload and no subjects successfully stowed the payload, much of the feedback received may have been perceived as negative. In either case, both process and outcome feedback would likely have similar effects on perceived competence.

Intrinsic motivation, though, may differentially affect performance, depending on the type of feedback received. Indeed, the results suggest that intrinsic motivation and feedback type interact in their effects on performance, providing support for Hypothesis 5. This interaction accounts for a significant increment in the variance accounted for by the regression models. Moreover, the relationships within feedback condition were as predicted. That is, intrinsic motivation was not related to performance in the process feedback condition, but higher intrinsic motivation was associated with better performance (i.e., fewer errors) in the outcome condition. Thus, there is evidence that intrinsic motivation plays a stronger role in the outcome feedback condition.

One other factor influencing intrinsic motivation was also examined: competence valuation. It was expected that feedback type would interact with competence valuation in its effects on intrinsic motivation (Hypothesis 6). That is, the extent to which subjects' valued competence on the task was assumed to play a more important role in the outcome feedback condition. Competence valuation was expected to be positively related to intrinsic motivation in the outcome condition but unrelated to intrinsic motivation in the process feedback condition. However, this hypothesis was not supported. The results revealed that competence valuation was positively associated with intrinsic motivation which is consistent with previous research (e.g., Harackiewcz & Larson, 1986; Sansone, 1986). However, there was no evidence that competence valuation was differentially related to intrinsic motivation, depending on the type of feedback provided. This may again be related to the perceived sign of feedback received (positive versus negative). That is, previous research suggests that feedback sign can influence competence valuation. Given that subjects in both feedback condition received veridical feedback, subjects in both conditions should perceive they have received either positive or negative feedback. Their perception of whether the feedback is positive or negative should influence competence valuation regardless of the type of feedback provided. Future research could address this issue by manipulating both feedback sign and type to separate their effects and enable the examination of relationships among feedback sign, type, and competence valuation in their effects on intrinsic motivation.

Finally, the results provided no evidence that self-esteem moderates the effect of feedback type on self-efficacy or that need for achievement moderates the effect of feedback type on intrinsic motivation (Hypotheses 7 and 8, respectively). As noted above, feedback sign may play a more important role in these effects, and subjects in both feedback conditions could perceive they had received either positive or negative feedback. Thus, to examine the possibly joint effects of feedback type and these individual difference variables, it may be necessary to first separate the effects of feedback sign and type.

An interesting question for future research is whether feedback sign has differential effects on self-efficacy, intrinsic motivation, and performance, depending on whether the positive or negative feedback is provided through process or outcome feedback. Past research has generally manipulated feedback sign using outcome feedback (e.g., Harackiewcz & Larson, 1986; Sansone, 1986). Indeed, it is unclear how process feedback can be provided which is positive versus negative. It may be necessary to provide process feedback with either a positive or negative evaluation associated with it. Alternately, one may state the process feedback in either constructive or destructive terms. Otherwise, one might manipulate the sign of process feedback by providing information only on what one did well versus what one did not do well although this may confound feedback sign with the usefulness of the information for correcting performance.

Future research is also needed to examine whether the results obtained generalize to other tasks and situations. The current study was a laboratory study with a task from a work setting but using college students as subjects. The subjects participated for course credit. It would be interesting to determine whether the same results would be obtained using employees who need the training to adequately perform their job.

In addition, there are other limitations on the conclusions one can draw from the current study resulting from the specific measures used. First, as discussed above, support for hypotheses was obtained using a general measure of self-efficacy. Further research using a more traditional, task-specific measure of self-efficacy is needed to determine whether the results generalize. Moreover, it would be of value to modify the administration of the intrinsic motivation measure. In the current study, intrinsic motivation, competence valuation, and perceived competence were assessed only following Cycle 6. However, it is possible that these variables change during task performance. Further research should obtain multiple measures of these variables to more systematically assess their role in the feedback type - performance relationship.

In conclusion, the current study provides evidence that process feedback is more beneficial to performance during the skill acquisition stage than is outcome feedback. Further, self-efficacy and intrinsic motivation play a more important role in influencing performance for individuals receiving outcome feedback than for those receiving process feedback. This is consistent with previous research which has used outcome feedback and found that higher self-efficacy and higher intrinsic motivation are associated with better performance. It may be that the high informational value of process feedback can enhance performance directly and thus reduce the importance of these other factors. Future research is needed to further examine the effects of process and outcome feedback on performance during a transfer test phase using multiple cycles. Research is also needed to further examine these relationships using improved measures of proposed moderating variables and to determine to what extent these results generalize to other tasks and situations. Finally, research is needed to investigate the joint effects of feedback sign and feedback type on performance and other factors influencing these relationships.

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Table 1

Effect of Feedback Condition on Performance in the Acquisition Phase.

| Source | *df* | *MS* | *F* |
|---|---|---|---|
| | | | 18.56** |
| | | | 0.83 |
| | | | 0.92 |
| | | | 7.41** |
| | | | 0.56 |
| | | | 5.27* |
| | | | 6.81* |
| | | | 1.22 |
| | | | 0.79 |
| | | | 3.45* |

Table 1 - Continued

Effect of Feedback Condition on Performance in the Acquisition Phase.

| Source | *df* | *MS* | *F* |
|---|---|---|---|
| | Number of Error Types | | |
| Cycle 1 Covariate | 1 | 33.27 | 6.91* |
| Feedback Condition | 1 | 20.897 | 4.34* |
| Between Subject Error | 51 | 4.82 | |
| Cycle | 3 | 0.20 | 0.10 |
| Cycle X Cycle 1 Covariate | 3 | 0.57 | 0.29 |
| Cycle X Feedback Condition | 3 | 2.32 | 1.17 |
| Within Subject Error | 153 | 1.98 | |

* $p < .05$. ** $p < .01$

Table 2

Means and SD's for Performance Measures in Cycles 2 through 6.

| Performance Measure | Cycle | Feedback Condition: Outcome Mean | Outcome SD | Process Mean | Process SD |
|---|---|---|---|---|---|
| Distance from Grapple | 2 | 79.83 | 98.78 | 62.95 | 62.04 |
| | 3 | 41.79 | 56.69 | 40.86 | 43.27 |
| | 4 | 58.99 | 98.88 | 34.39 | 54.59 |
| | 5 | 31.78 | 58.83 | 22.01 | 29.38 |
| | 6 | 40.49 | 67.87 | 20.60 | 35.32 |
| Number of Errors | 2 | 6.11 | 4.70 | 4.33 | 3.69 |
| | 3 | 7.26 | 5.67 | 4.92 | 4.29 |
| | 4 | 6.30 | 5.44 | 5.15 | 4.36 |
| | 5 | 8.44 | 7.65 | 3.07 | 3.02 |
| | 6 | 9.89 | 5.83 | 5.67 | 4.65 |
| Number of Error Types | 2 | 3.15 | 2.12 | 2.48 | 1.87 |
| | 3 | 2.92 | 1.38 | 2.55 | 1.69 |
| | 4 | 2.70 | 1.44 | 2.59 | 1.65 |
| | 5 | 2.96 | 1.58 | 1.89 | 1.55 |
| | 6 | 4.04 | 1.83 | 2.96 | 1.72 |

Table 3

Frequency of Grapple Success in Cycles 2 through 6.

| | Feedback Condition | | | | |
|---|---|---|---|---|---|
| | Outcome | | Process | | |
| Cycle | Number | % | Number | % | $\chi^2$ |
| 2 | 4 | 14.81 | 0 | 0.00 | 4.32* |
| 3 | 6 | 22.22 | 3 | 11.11 | 1.20 |
| 4 | 9 | 33.33 | 6 | 22.22 | 0.83 |
| 5 | 13 | 48.15 | 10 | 37.04 | 0.68 |
| 6 | 10 | 37.04 | 9 | 33.33 | 0.08 |

* $p < .05$. ** $p < .01$

Table 4

Means and SD's for Specific Error Types in Cycles 2 through 5.

| Performance Measure | Cycle | Feedback Condition: Outcome Mean | Outcome SD | Process Mean | Process SD |
|---|---|---|---|---|---|
| Singularity | 2 | 1.11 | 1.72 | 1.07 | 1.59 |
| | 3 | 1.85 | 3.30 | 1.55 | 2.45 |
| | 4 | 1.48 | 2.99 | 1.78 | 2.08 |
| | 5 | 1.70 | 2.64 | 0.81 | 1.11 |
| Touching Payload | 2 | 0.48 | 0.70 | 0.48 | 0.75 |
| | 3 | 0.59 | 1.05 | 0.74 | 1.02 |
| | 4 | 0.59 | 0.75 | 0.81 | 0.88 |
| | 5 | 0.92 | 1.41 | 0.44 | 0.70 |
| EE Engagement Distance | 2 | 1.92 | 1.68 | 1.00 | 1.33 |
| | 3 | 1.48 | 2.17 | 0.96 | 1.53 |
| | 4 | 1.11 | 1.82 | 0.63 | 1.39 |
| | 5 | 1.33 | 2.87 | 0.63 | 1.57 |
| Backing Up | 2 | 1.67 | 1.80 | 0.52 | 0.89 |
| | 3 | 1.55 | 1.82 | 0.67 | 0.96 |
| | 4 | 1.74 | 2.26 | 1.07 | 1.44 |
| | 5 | 2.55 | 3.20 | 0.70 | 1.07 |

Table 4 - Continued

Means and SD's for Specific Error Types in Cycles 2 through 5.

| Performance Measure | Cycle | Feedback Condition: Outcome Mean | Outcome SD | Process Mean | Process SD |
|---|---|---|---|---|---|
| EE Mode Button Errors | 2 | 0.70 | 1.54 | 0.11 | 0.42 |
| | 3 | 0.92 | 2.16 | 0.37 | 0.88 |
| | 4 | 0.67 | 1.62 | 0.26 | 0.98 |
| | 5 | 0.85 | 2.68 | 0.00 | 0.00 |

Table 5

Intercorrelations between Error Types in Cycles 2 through 5.

| Measure | Sing. | Touch. | EE Eng. | Backing | EE Mode |
|---|---|---|---|---|---|
| | | Cycle 2 | | | |
| Singularity | -- | | | | |
| Touching Payload | .50** | -- | | | |
| EE Engagement Distance | -.23 | -.09 | -- | | |
| Backing Up | .28* | .35** | .12 | -- | |
| EE Mode Button Errors | -.13 | -.08 | .58** | .20 | -- |
| | | Cycle 3 | | | |
| Singularity | -- | | | | |
| Touching Payload | .36** | -- | | | |
| EE Engagement Distance | -.22 | -.02 | -- | | |
| Backing Up | .53** | .38** | .05 | -- | |
| EE Mode Button Errors | -.15 | -.10 | .57** | -.07 | -- |
| | | Cycle 4 | | | |
| Singularity | -- | | | | |
| Touching Payload | .39** | -- | | | |
| EE Engagement Distance | -.19 | -.16 | -- | | |
| Backing Up | .09 | .34** | .30* | -- | |
| EE Mode Button Errors | -.05 | .04 | .55** | .46** | -- |

* $p < .05$. ** $p < .01$

Table 5 - Continued

Intercorrelations between Error Types in Cycles 2 through 5.

| Measure | Sing. | Touch. | EE Eng. | Backing | EE Mode |
|---|---|---|---|---|---|
| | | Cycle 5 | | | |
| Singularity | -- | | | | |
| Touching Payload | .55** | -- | | | |
| EE Engagement Distance | -.03 | -.19 | -- | | |
| Backing Up | .44** | .67** | -.10 | -- | |
| EE Mode Button Errors | -.02 | -.11 | .76** | .01 | -- |

* $p$ < .05. ** $p$ < .01

Table 6

Effects of Feedback Condition on Specific Error Types in the Acquisition Phase.

| Source | *df* | *MS* | *F* |
|---|---|---|---|
| | | Singularity | |
| Cycle 1 Covariate | 1 | 132.17 | 12.99** |
| Feedback Condition | 1 | 8.14 | 0.80 |
| Between Subject Error | 51 | 10.17 | |
| Cycle | 3 | 2.30 | 0.72 |
| Cycle X Cycle 1 Covariate | 3 | 1.41 | 0.44 |
| Cycle X Feedback Condition | 3 | 3.19 | 1.00 |
| Within Subject Error | 153 | 3.18 | |
| | | Touching Payload | |
| Cycle 1 Covariate | 1 | 9.00 | 7.25** |
| Feedback Condition | 1 | 0.16 | 0.13 |
| Between Subject Error | 51 | 1.24 | |
| Cycle | 3 | 0.49 | 0.69 |
| Cycle X Cycle 1 Covariate | 3 | 0.23 | 0.32 |
| Cycle X Feedback Condition | 3 | 1.34 | 1.88 |
| Within Subject Error | 153 | 0.71 | |

* $p < .05$. ** $p < .01$

Table 6 - Continued

Effects of Feedback Condition on Specific Error Types in the Acquisition Phase.

| Source | *df* | *MS* | *F* |
|---|---|---|---|
| | EE Engagement Distance | | |
| Cycle 1 Covariate | 1 | 42.34 | 4.62* |
| Feedback Condition | 1 | 6.85 | 0.75 |
| Between Subject Error | 51 | 9.17 | |
| Cycle | 3 | 1.23 | 0.97 |
| Cycle X Cycle 1 Covariate | 3 | 4.48 | 3.51 |
| Cycle X Feedback Condition | 3 | 1.76 | 1.38 |
| Within Subject Error | 153 | 1.28 | |
| | Backing Up | | |
| Cycle 1 Covariate | 1 | 10.18 | 1.95 |
| Feedback Condition | 1 | 68.44 | 13.13** |
| Between Subject Error | 51 | 5.21 | |
| Cycle | 3 | 3.75 | 1.39 |
| Cycle X Cycle 1 Covariate | 3 | 2.81 | 1.04 |
| Cycle X Feedback Condition | 3 | 3.45 | 1.27 |
| Within Subject Error | 153 | 2.71 | |

* $p < .05$. ** $p < .01$

Table 6 - Continued

Effects of Feedback Condition on Specific Error Types in the Acquisition Phase.

| Source | df | MS | F |
|---|---|---|---|
| | EE Mode Button Errors | | |
| Cycle 1 Covariate | 1 | 15.41 | 2.11 |
| Feedback Condition | 1 | 15.08 | 2.06 |
| Between Subject Error | 51 | 7.32 | |
| Cycle | 3 | 1.04 | 1.63 |
| Cycle X Cycle 1 Covariate | 3 | 0.81 | 1.27 |
| Cycle X Feedback Condition | 3 | 0.41 | 0.65 |
| Within Subject Error | 153 | 0.64 | |

* $p < .05$. ** $p < .01$

Table 7

Effect of Feedback Condition on Performance in the Transfer Test.

| Source | *df* | *MS* | *F* |
|---|---|---|---|
| | Distance from Grapple | | |
| Cycle 2-5 Covariate | 1 | 66994.29 | 37.60** |
| Feedback Condition | 1 | 1597.76 | 0.90 |
| Error | 49 | 1781.64 | |
| | Number of Errors | | |
| Cycle 2-5 Covariate | 1 | 836.37 | 52.61** |
| Feedback Condition | 1 | 40.19 | 2.53 |
| Error | 51 | 15.90 | |
| | Number of Error Types | | |
| Cycle 2-5 Covariate | 1 | 46.30 | 18.53** |
| Feedback Condition | 1 | 5.76 | 2.30 |
| Error | 51 | 2.50 | |

* $p < .05$. ** $p < .01$

Table 8

Effect of Feedback Condition and Task-Specific Self-Efficacy on Performance.

| Predictors | $R^2$ | $F$ (df) | Beta | SD[t] | $\Delta R^2$ | $F$ (df) |
|---|---|---|---|---|---|---|
| Cycle 2: Model 1 | .19 | 3.99 (3, 50)* | | | | |
| Covariate | | | .38** | 5.28 | | |
| Feedback Cond. | | | -.21 | .50 | | |
| Self-Efficacy | | | -.04 | 17.94 | | |
| Cycle 2: Model 2 | .25 | 4.03 (4, 49)** | | | .06 | 3.62 (1, 50) |
| Covariate | | | .38** | 5.28 | | |
| Feedback Cond. | | | -.55* | .50 | | |
| Self-Efficacy | | | -.23 | 17.94 | | |
| Fdbk X SEffic | | | .46 | 17.26 | | |
| Cycle 5: Model 1 | .24 | 5.30 (3, 50)** | | | | |
| Covariate | | | .22 | 5.28 | | |
| Feedback Cond. | | | -.42** | .50 | | |
| Self-Efficacy | | | -.10 | 17.94 | | |
| Cycle 5: Model 2 | .28 | 4.82 (4, 49)** | | | .04 | 2.85 (1, 50) |
| Covariate | | | .22 | 5.28 | | |
| Feedback Cond. | | | -.71** | .50 | | |
| Self-Efficacy | | | -.27 | 17.94 | | |
| Fdbk X SEffic | | | .41 | 17.26 | | |

* $p < .05$. ** $p < .01$. Performance Cycle 2 SD = 4.28; Cycle 5 SD = 6.36.

[t] Standard deviations (SD's) are provided so unstandardized (raw) regression weights, b's, can be computed: b = Beta ( $SD_y$ / $SD_x$ ).

Table 9

Effects of Feedback Condition and General Self-Efficacy on Performance.

| Predictors | $R^2$ | $F$ ($df$) | Beta | $SD$[t] | $\Delta R^2$ | $F$ ($df$) |
|---|---|---|---|---|---|---|
| Cycle 2: Model 1 | .19 | 3.97 (3, 50)* | | | | |
| Covariate | | | .38** | 5.28 | | |
| Feedback Cond. | | | -.21 | .50 | | |
| Self-Efficacy | | | -.03 | 3.39 | | |
| Cycle 2: Model 2 | .23 | 3.67 (4, 49)** | | | .04 | 2.50 (1, 50) |
| Covariate | | | .40** | 5.28 | | |
| Feedback Cond. | | | -.52* | .50 | | |
| Self-Efficacy | | | -.18 | 3.39 | | |
| Fdbk X SEffic | | | .42 | 3.60 | | |
| Cycle 5: Model 1 | .24 | 5.30 (3, 50)** | | | | |
| Covariate | | | .21 | 5.28 | | |
| Feedback Cond. | | | -.43** | .50 | | |
| Self-Efficacy | | | -.15 | 3.83 | | |
| Cycle 5: Model 2 | .28 | 4.82 (4, 49)** | | | .08 | 5.63 (1, 50)* |
| Covariate | | | .20 | 5.28 | | |
| Feedback Cond. | | | -.88** | .50 | | |
| Self-Efficacy | | | -.41* | 3.83 | | |
| Fdbk X SEffic | | | .57* | 4.00 | | |

* $p < .05$. ** $p < .01$. Performance Cycle 2 $SD$ = 4.28; Cycle 5 $SD$ = 6.36.

[t] Standard deviations ($SD$'s) are provided so unstandardized (raw) regression weights, $b$'s, can be computed: $b = \text{Beta} \, ( SD_y / SD_x )$.

Table 10

Effects of Feedback Condition and Intrinsic Motivation on Performance.

| Predictors | $R^2$ | $F$ ($df$) | Beta | SD[c] | $\Delta R^2$ | $F$ ($df$) |
|---|---|---|---|---|---|---|
| Cycle 2: Model 1 | .20 | 4.14 (3, 50)** | | | | |
| Covariate | | | .39** | 5.28 | | |
| Feedback Cond. | | | -.20 | .50 | | |
| Intrinsic Mot. | | | -.09 | 1.36 | | |
| Cycle 2: Model 2 | .26 | 4.22 (4, 49)** | | | .06 | 4.26 (1, 50)* |
| Covariate | | | .38** | 5.28 | | |
| Feedback Cond. | | | -1.07* | .50 | | |
| Intrinsic Mot. | | | -.34 | 1.36 | | |
| Fdbk X Int Mot | | | .95 | 2.71 | | |
| Cycle 5: Model 1 | .26 | 5.97 (3, 50)** | | | | |
| Covariate | | | .23 | 5.28 | | |
| Feedback Cond. | | | -.41** | .50 | | |
| Intrinsic Mot. | | | -.18 | 1.36 | | |
| Cycle 5: Model 2 | .32 | 5.84 (4, 49)** | | | .06 | 4.37 (1, 50)* |
| Covariate | | | .23 | 5.28 | | |
| Feedback Cond. | | | -1.30** | .50 | | |
| Intrinsic Mot. | | | -.44* | 1.36 | | |
| Fdbk X Int Mot | | | .97* | 2.71 | | |

* $p < .05$. ** $p < .01$. Performance Cycle 2 SD = 4.28; Cycle 5 SD = 6.36.

[c] Standard deviations (SD's) are provided so unstandardized (raw) regression weights, b's, can be computed: b = Beta ( $SD_y$ / $SD_x$ ).

Table 11

Effects of Feedback Condition and Competence Valuation on Intrinsic Motivation.

| Predictors | $R^2$ | $F$ (df) | Beta | SD[t] | $\Delta R^2$ | $F$ (df) |
|---|---|---|---|---|---|---|
| Model 1 | .12 | 3.63 (2, 51)* | | | | |
| Feedback Cond. | | | .07 | .50 | | |
| Competence Val. | | | .34* | 1.26 | | |
| Model 2 | .12 | 2.39 (3, 50) | | | .00 | 0.04 (1, 50) |
| Feedback Cond. | | | -.03 | .50 | | |
| Competence Val. | | | .32 | 1.26 | | |
| Fdbk X Comp Val | | | .11 | 2.77 | | |

* $p < .05$. ** $p < .01$. Intrinsic Motivation SD = 1.36.

[t] Standard deviations (SD's) are provided so unstandardized (raw) regression weights, b's, can be computed: b = Beta ( $SD_y$ / $SD_x$ ).

Table 12

Effects of Individual Difference Factors on Feedback Effects on Self-Efficacy and Intrinsic Motivation.

| Predictors | $R^2$ | $F$ ($df$) | Beta | SD[a] | $\Delta R^2$ | $F$ ($df$) |
|---|---|---|---|---|---|---|
| | | | Self-Efficacy | | | |
| Model 1 | .02 | 0.61 (2, 51) | | | | |
| Feedback Cond. | | | -.04 | .50 | | |
| Self-Esteem | | | .14 | 3.99 | | |
| Model 2 | .04 | 0.80 (3, 50) | | | .02 | 1.21 (1, 50) |
| Feedback Cond. | | | .66 | .50 | | |
| Self-Esteem | | | .32 | 3.99 | | |
| Fdbk X SE | | | -.73 | 9.55 | | |
| | | | Intrinsic Motivation | | | |
| Model 1 | .03 | 0.81 (2, 51) | | | | |
| Feedback Cond. | | | .08 | .50 | | |
| Need for Work | | | -.16 | 2.42 | | |
| Model 2 | .09 | 1.62 (3, 50) | | | .06 | 3.23 (1, 50) |
| Feedback Cond. | | | .28 | .50 | | |
| Need for Work | | | .13 | 2.42 | | |
| Fdbk X NW | | | -.42 | 2.11 | | |

* $p < .05$. ** $p < .01$.

Self-Efficacy $SD$ = 3.83. Intrinsic Motivation $SD$ = 1.36.

[a] Standard deviations ($SD$'s) are provided so unstandardized (raw) regression weights, $b$'s, can be computed: $b = \text{Beta}\ ( SD_y \ / \ SD_x )$.

Figure 1. Shuttle Axes.

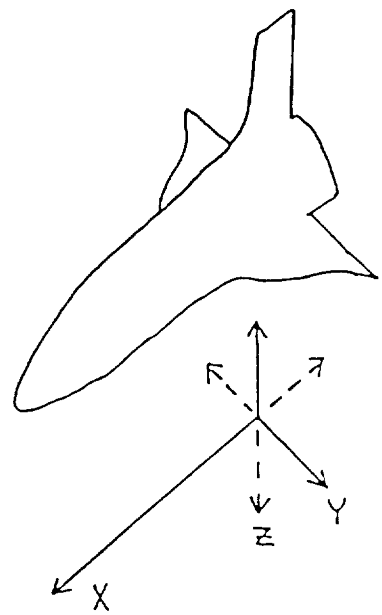


Figure 2. Location of Cameras on Shuttle.

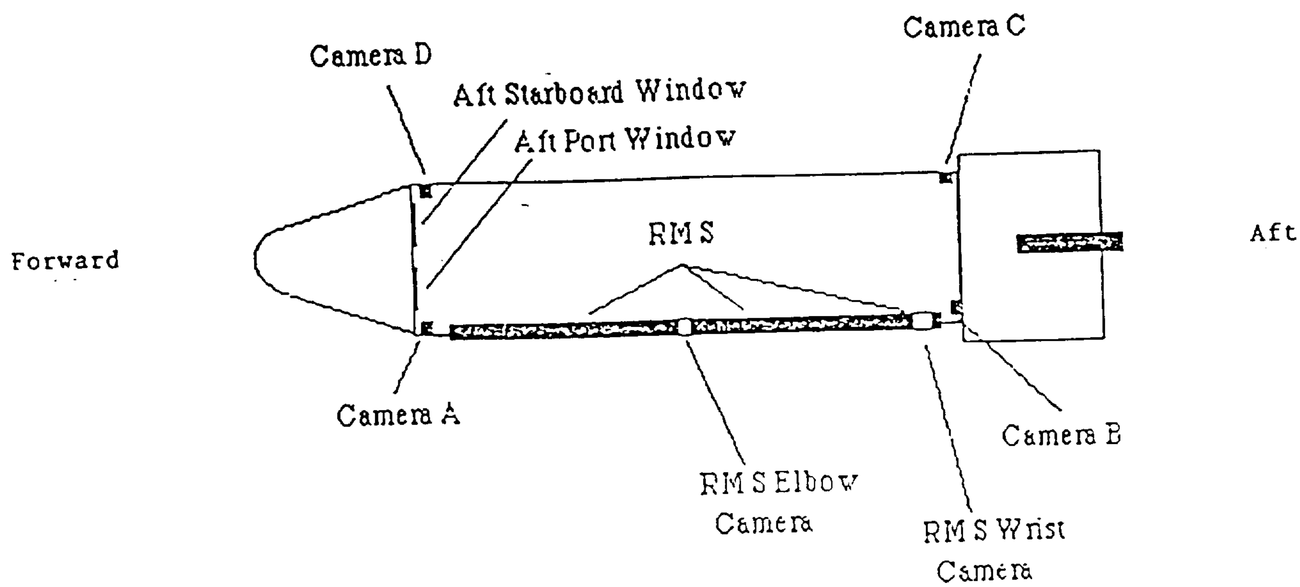
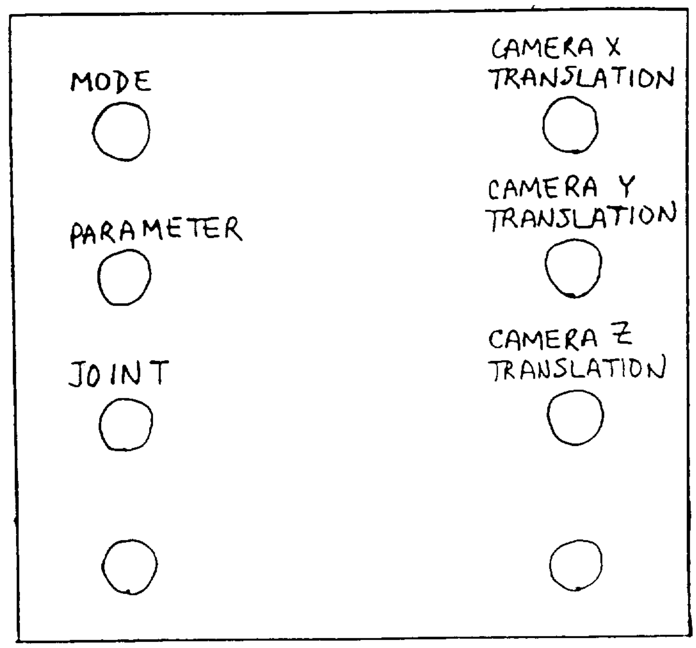
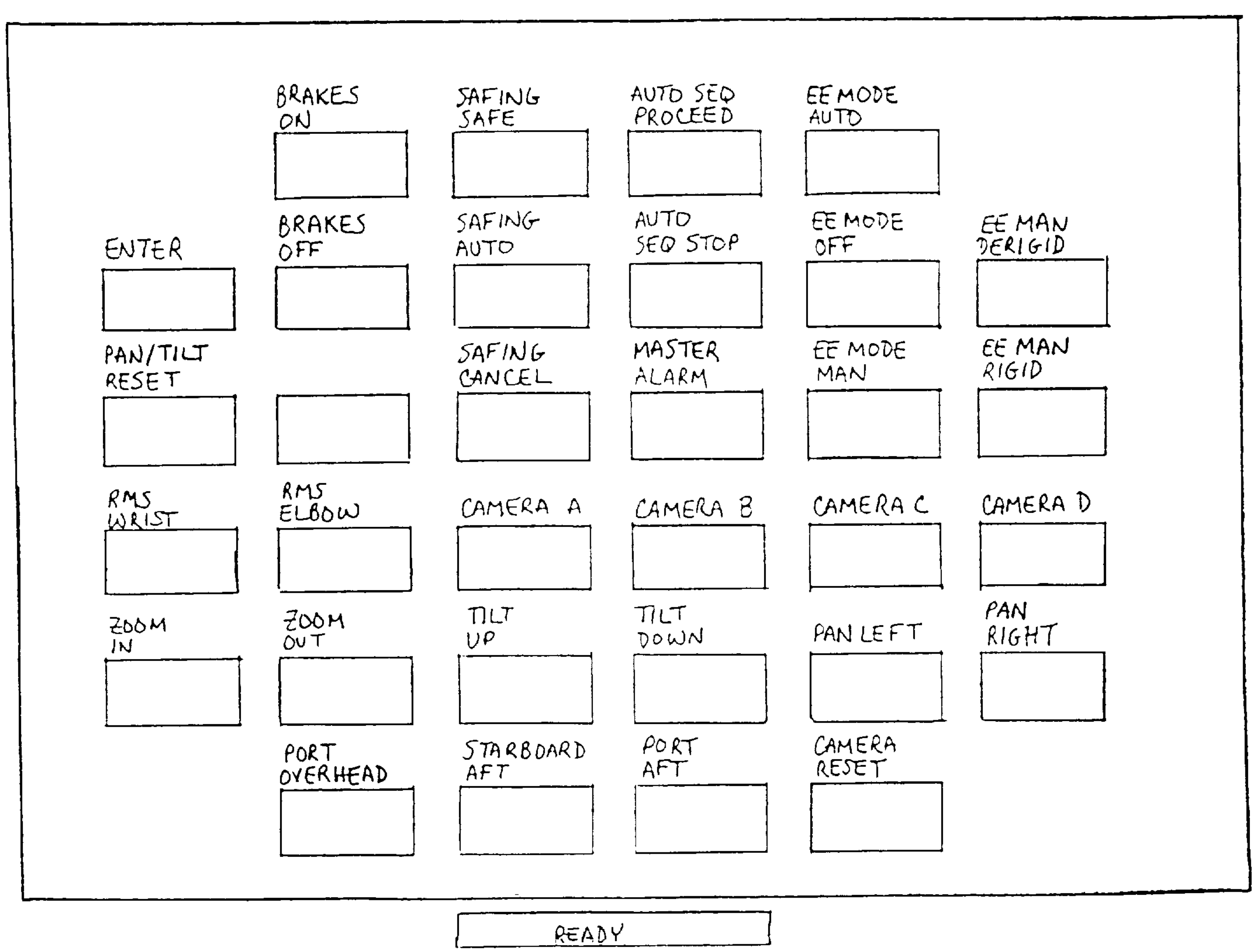


Figure 3. Control Box for Using RMS Simulation



1. Do not get into singularity
2. Do not lock up the RMS.
3. Do not move any part of the payload through the payload bay.
4. Do not move any part of the payload through the guide posts.
5. Do not move any part of the payload through the notch walls.
6. Do not move any part of the payload through the bottom of the notch.
7. You must have the levers rest on the bottom of the notch.
8. Do not stow the payload incorrectly by having the payload's embedded bar levers off center (i.e., only one lever is resting on the set of notches).
9. Do not touch the payload with the end effector.
10. Do not engage in EE Auto mode from too far a distance.
11. Do not move the end effector with the payload before the top three indicator lights change from striped to white.
12. Do not move the end effector away from the payload before the top three indicator lights change from white to striped.
13. Do not stow the payload in a different area of the payload bay.
14. Do not overshoot the payload when trying to grapple.
15. Do not overshoot the guide posts when stowing.
16. Do not back up.
17. Do not overshoot a desired joint angle.
18. Engage in vernier mode when the levers are in sight of the guide posts with Camera B or Camera C.
19. Do not press a wrong button on the control box.
20. Do not press a wrong button on the joystick.
21. You must move Camera B or Camera C back to its original location as the payload is being lowered into the payload bay.
22. You must move Camera B or Camera C so that it shows the guide post on the other side of the bay as soon as the payload levers are between the guide posts.
23. Do not move the controls before engaging in end effector mode.
24. Do not engage in any mode other than end effector mode.
25. Do not move the joystick and the translator at the same time.
26. Do not operate the RMS and operate the cameras at the same time.
27. You are to move the RMS at least 24 inches away from the payload on the <u>X</u> axis.

<u>Process Feedback</u>

1. You reached singularity. Make sure you don't extend the arm to far out.
2. You locked the RMS up. Be aware of all three RMS joint angles.
3. You moved the payload through the payload bay. Make sure that you are aware of where the payload is at all times.
4. Don't go through the guide posts when stowing the payload.
5. Don't go through the notch walls when stowing the payload.
6. Make sure you stop the RMS when you reach the bottom of the notch.
7. Make sure you bring the levers all the way down to the bottom of the notch.
8. You stowed the payload incorrectly. The payload was off center. Make sure both levels are resting on the bottom of the notch.
9. Don't touch the payload with the end effector.
10. You were too far away from the payload before engaging in EE Auto mode.
11. Don't try to move the end effector with the payload until the control panel change from striped to white.
12. Don't try to move the end effector away from the payload until the control panel lights change from white to striped.
13. You did not stow the payload in the correct location. Make sure the lever bars go through the yellow guide posts and rest on the bottom of the notch.
14. You overshot the payload. You may need to go slower or be more aware of where you are in relation to the payload.
15. You overshot the guide posts. You may need to go slower or be more aware of where you are in relation to the posts.
16. You backed up. Don't get yourself in a position where you have to back up.
17. You moved a joint angle to far and had to move the angle in the opposite direction. Use vernier mode when you need to more slowly or be precise in your movement of the RMS.
18. Engage in vernier mode when the levers are in sight of the guide posts with Camera B or Camera C.
19. You pressed the wrong button on the control box (**describe sequence**, e.g., hitting the enter button when engaging in EE Auto Mode).
20. You pressed the wrong button on the joy stick (**describe sequence**, e.g., hitting the center button and then the left one to disengage the end effector from the payload.
21. I had to move the camera so that it shows a full view of the guide post and notch. You are to move the camera back to that location when you start to lower the payload into the payload bay.
22. I had to move the camera so that it shows a full view of the opposite guide post and notch. You are to move both Cameras B & C to those locations as soon as the levers are in between the guide posts.
23. You moved the controls before engaging in end effector mode.
24. You engaged in a mode other than end effector.
25. You moved the joy stick and translator at the same time. For now, only move one control at a time.
26. You operated the RMS and the cameras at the same time. For now operate only one thing at a time.
27. You did not move the RMS back enough so that the entire octagonal hookup was in view of the wrist camera.

Appendix C. Self-Efficacy Questionnaire

**Subject ID** ____________________ **Date** ____________________

**Prior to Cycle** ____________________

**Directions: Please read the statements below. For each statement, indicate how confident you are that you will be able to perform at that level. Circle a number between 1 and 10 to indicate your confidence.**

1 - no confidence at all 10 - total confidence

| | |
|---|---|
| 1 2 3 4 5 6 7 8 9 10 | I can grapple and correctly stow the payload, making no more than 14 types of errors. |
| 1 2 3 4 5 6 7 8 9 10 | I can grapple and correctly stow the payload, making no more than 12 types of errors. |
| 1 2 3 4 5 6 7 8 9 10 | I can grapple and correctly stow the payload, making no more than 10 types of errors. |
| 1 2 3 4 5 6 7 8 9 10 | I can grapple and correctly stow the payload, making no more than 8 types of errors. |
| 1 2 3 4 5 6 7 8 9 10 | I can grapple and correctly stow the payload, making no more than 6 types of errors. |
| 1 2 3 4 5 6 7 8 9 10 | I can grapple and correctly stow the payload, making no more than 4 types of errors. |
| 1 2 3 4 5 6 7 8 9 10 | I can grapple and correctly stow the payload, making no more than 2 types of errors. |
| 1 2 3 4 5 6 7 8 9 10 | I can grapple and correctly stow the payload, making no errors. |
| 1 2 3 4 5 6 7 8 9 10 | I can grapple the payload, regardless of the number of errors that are made. |
| 1 2 3 4 5 6 7 8 9 10 | I can stow the payload, regardless of the number of errors that are made. |

Appendix D. **Post Task Questionnaire**

**Subject** ____________ **Date** ____________ **Coder**____________

**Directions: Please read each item carefully. Circle the number that best corresponds to your opinion using the following scale:**

**1. How much did you enjoy this task?**

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| Very Much | | | | | | Not at all |

**2. I felt very tense while playing.**

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| Strongly Disagree | Disagree | Slightly Disagree | Neither Disagree nor Agree | Slightly Agree | Agree | Strongly Agree |

**3. How believable was the feedback that you received?**

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| Very Believable | | | | | | Not Believable |

**4. This task was fun.**

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| Strongly Disagree | Disagree | Slightly Disagree | Neither Disagree nor Agree | Slightly Agree | Agree | Strongly Agree |

**5. The feedback that I received help me perform better.**

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| Strongly Disagree | Disagree | Slightly Disagree | Neither Disagree nor Agree | Slightly Agree | Agree | Strongly Agree |

**6. How useful was the feedback?**

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| Very Useful | | | | | | Not Useful |

**7. It was important for me to do well.**

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| Strongly Disagree | Disagree | Slightly Disagree | Neither Disagree nor Agree | Slightly Agree | Agree | Strongly Agree |

**8. How well did you think you did compared to other students?**

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| Very Well | | | | | | Not Well |

**9. The feedback I received helped me figure out what I had to do to learn this task faster.**

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| Strongly Disagree | Disagree | Slightly Disagree | Neither Disagree nor Agree | Slightly Agree | Agree | Strongly Agree |

**10. This task was boring.**

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| Strongly Disagree | Disagree | Slightly Disagree | Neither Disagree nor Agree | Slightly Agree | Agree | Strongly Agree |

**11. I cared very much about how well I did.**

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| Strongly Disagree | Disagree | Slightly Disagree | Neither Disagree nor Agree | Slightly Agree | Agree | Strongly Agree |

**12. It seemed that I had very little control over how well I did.**

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| Strongly Disagree | Disagree | Slightly Disagree | Neither Disagree nor Agree | Slightly Agree | Agree | Strongly Agree |

**13. I had a lot of interest in this task.**

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| Strongly Disagree | Disagree | Slightly Disagree | Neither Disagree nor Agree | Slightly Agree | Agree | Strongly Agree |

**14. I tried very hard at this task.**

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| Strongly Disagree | Disagree | Slightly Disagree | Neither Disagree nor Agree | Slightly Agree | Agree | Strongly Agree |

**15. How helpful was the feedback?**

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| Very Helpful | | | | | | Not Helpful |

16. I performed poorly on this task.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| Strongly Disagree | Disagree | Slightly Disagree | Neither Disagree nor Agree | Slightly Agree | Agree | Strongly Agree |

17. This task was enjoyable.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| Strongly Disagree | Disagree | Slightly Disagree | Neither Disagree nor Agree | Slightly Agree | Agree | Strongly Agree |

18. The feedback I received helped me figure out what I could do to improve my performance.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| Strongly Disagree | Disagree | Slightly Disagree | Neither Disagree nor Agree | Slightly Agree | Agree | Strongly Agree |

19. This task was absorbing.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| Strongly Disagree | Disagree | Slightly Disagree | Neither Disagree nor Agree | Slightly Agree | Agree | Strongly Agree |

20. The amount of effort put in, that is, how hard I tried, really determined how well I performed on the task.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| Strongly Disagree | Disagree | Slightly Disagree | Neither Disagree nor Agree | Slightly Agree | Agree | Strongly Agree |

21. I performed well on this task.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| Strongly Disagree | Disagree | Slightly Disagree | Neither Disagree nor Agree | Slightly Agree | Agree | Strongly Agree |

**22. The feedback that I received was useful.**

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| **Strongly Disagree** | **Disagree** | **Slightly Disagree** | **Neither Disagree nor Agree** | **Slightly Agree** | **Agree** | **Strongly Agree** |

**23. To what extent did you change the way you performed the task as a result of the feedback provided to you.**

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| To a great extent | | | | | | Not at all |

**24. Please <u>rank order</u> the following four factors regarding their importance in determining your performance.**

1 = The most important factor; 2 = The second most important factor;
3 = The third most important factor; 4 = The least important factor

__________ a) luck
__________ b) task difficulty
__________ c) effort
__________ d) ability

Appendix E. Participation Consent Form

Please read the consent form below before we begin.

You are invited to participate in a research project involving a computerized task. The purpose of the study is to learn more about training on computerized tasks. You will receive extra credit points to be applied to your Psychology point total.

In this session you will be working on a object movement task. The session lasts about 3 hours. Instructions for the task are provided in the session. You will work on the task for six, 15 minute trials and complete short questionnaires following task trials.

Information obtained in the project will be identified by a code number. No one will be identified by name, and only group data will be presented in any subsequent written reports of the project. Your name will be used only to indicate that you participated in the project so that you can receive extra credit points.

Your decision on whether to participate in the project will have no effect on your academic performance except for the provision of extra credit points. You are free to withdraw from participation now or at any time in the session without penalty. There is no risk or discomfort involved in the project.

Please ask the experimenter any questions that you have. Please contact Debra Johnson (Department of Psychology, 127B Heyne, 749-6131) if you have additional questions or comments.

Thank you for your cooperation.

---

I, ______________________________, have read the
(Please print your name)

information provided above and have decided to participate. I understand that my participation is voluntary, I also understand that I may withdraw at any time without prejudice after signing the form should I choose to discontinue participation in this study.

______________________________ ____________

Signature of Participant Date

______________________________
Signature of Experimenter

THIS PROJECT WAS REVIEWED BY THE UNIVERSITY OF HOUSTON

COMMITTEE FOR THE PROTECTION OF HUMAN SUBJECTS (PHONE: 749-3412).

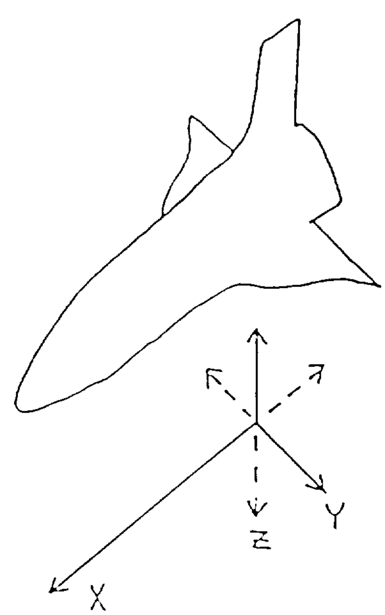
Appendix F. **Task Instructions**

You are about to learn how to operate the space shuttle orbiter's Remote Manipulation System (RMS). The RMS is analogous to your arm in that it has three joints: the wrist, elbow and shoulder. The RMS is used to lift and deploy payloads such as satellites. The task that you will perform is to grab, or grapple, the payload and stow it in the orbiter payload bay.

To start the program turn the Mode Dial until the dial on the left side of the monitor points at End Effector. Then, hit the Enter Button on the control box.

You operate the RMS with the translator and joystick. The gray handle on the left side of the chair is called the translator. The translator moves the RMS along three axes: X, Y, and Z. The X axis goes from the front of the orbiter to the back (see Figure 1). Pushing (pulling) the handle moves the RMS forward (back). The Y axis goes from the left side of the orbiter to the right side. Moving the translator to the left (right) moves the RMS to the left (right). The Z axis runs from the top of the orbiter to the bottom. Moving the translator up (down) moves the RMS up (down). Note that you can go in more than one direction. For example, you can translate forward and up at the same time.

Figure 1



A joystick is on the right side of the chair. The joystick rotates the end effector (the tip of the RMS). Move the joystick forward and back to rotate the end effector around the Y axis. That rotation is called pitch. Move the joystick from side to side to roll the end effector around the X axis. This movement is called roll. Twist the joystick around (clockwise or counterclockwise) to rotate the end effector around the Z axis. The side to side movement is called yaw. Yaw refers to rotation around the Z axis. It is important to remember that using the joystick results in different movements than those that occur with the translator.

You might find it easier to use the translator when moving the RMS. The joystick may be useful when aligning the payload with the payload bay, and aligning the end effector with the payload.

YOUR TASK

The Payload

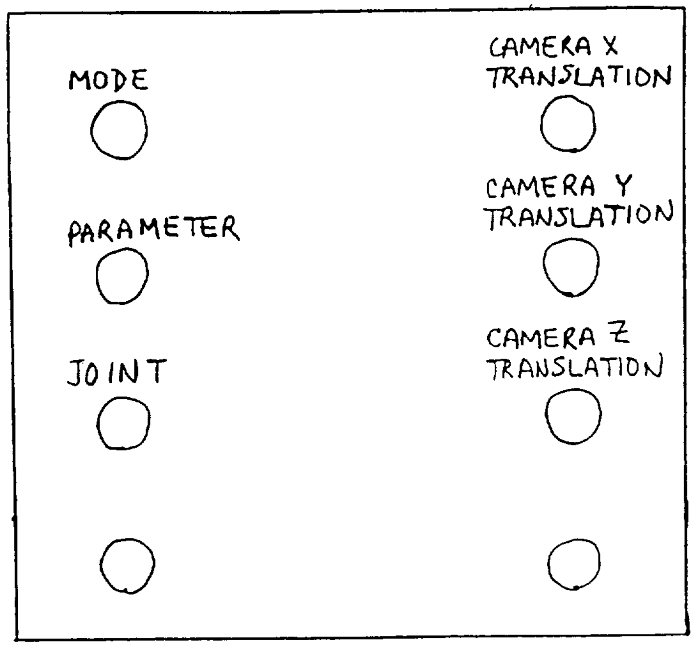
Your task objective is to grapple the payload and stow it in the payload bay. The payload is the octagonal aqua object. It has a light gray bar embedded along its top. Note that the bar extends out from both sides of the payload. The octagon has a rod extending from its center. On top of this figure is a black bar. In the center of the bar is a white circle, and a white rod. When grappling the payload, position the end effector so that it is within a few inches of the flat part of the octagon. Moving the end effector so that the white rod appears as a dot located in the center of the white circle ensures that you are heading in the right direction. You can best see the white rod and circle with the wrist camera.

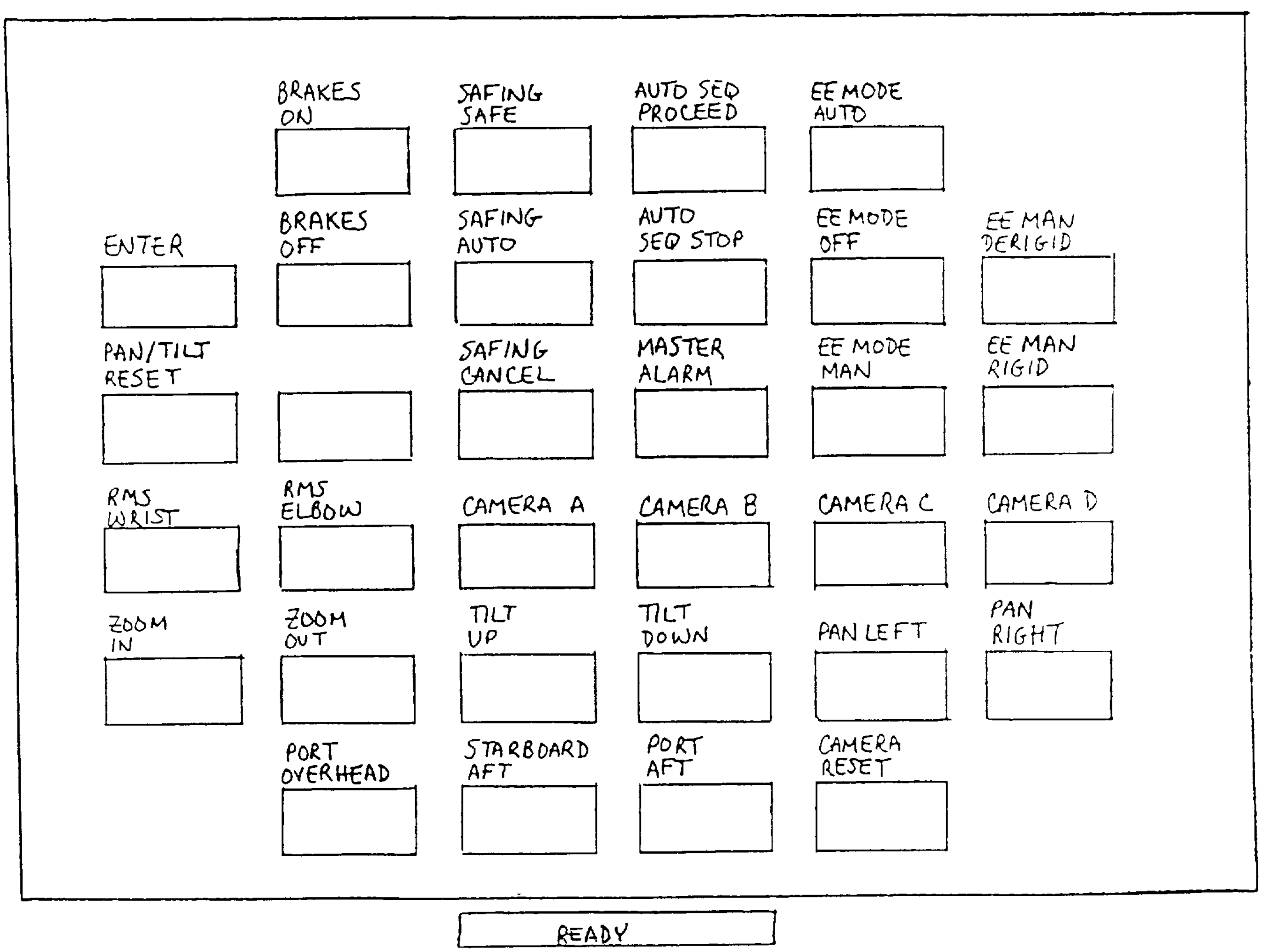
Grappling the Payload

When you are about to touch the octagon with the RMS you will engage in End Effector Auto Mode. End effector auto mode automatically moves the end effector so that it is properly aligned with the payload, attaches itself to the payload, and grapples it.

To engage in End Effector auto mode hit the EE Mode Auto button on the control box (see Figure 2). Then pull the trigger on the joystick. Squeezing the trigger activates the 2 rows of three lights on the right side of the monitor's control panel. You've grappled the payload when all three lights on the top row change from striped to white. The lights take about 30-45 seconds to change color. When all three lights change you are ready to move the payload. If you engage in end effector auto mode before you are close enough to the payload, some of the lights will not change color after about 45 seconds. You have to disengage from auto mode and try again. The Task Completion section indicates how to disengage from the payload.

Figure 2


MODE
PARAMETER
JOINT
CAMERA X TRANSLATION
CAMERA Y TRANSLATION
CAMERA Z TRANSLATION


BRAKES ON
SAFING SAFE
AUTO SEQ PROCEED
EE MODE AUTO
ENTER
BRAKES OFF
SAFING AUTO
AUTO SEQ STOP
EE MODE OFF
EE MAN DERIGID
PAN/TILT RESET
SAFING CANCEL
MASTER ALARM
EE MODE MAN
EE MAN RIGID
RMS WRIST
RMS ELBOW
CAMERA A
CAMERA B
CAMERA C
CAMERA D
ZOOM IN
ZOOM OUT
TILT UP
TILT DOWN
PAN LEFT
PAN RIGHT
PORT OVERHEAD
STARBOARD AFT
PORT AFT
CAMERA RESET
READY

Stowing the Payload

You will move the payload into the payload bay to stow it. The front of the payload bay contains a set of yellow guide posts that sit on top of a notch. To stow the payload correctly, you have to maneuver it so that each side of the payload's gray bar touches the bottom of the notch.

Task Completion

To complete the task, you need to release the payload and then move the RMS to its end position. When you want to disengage from auto mode or to release the payload from the RMS, press the far left black button near the top of the joystick. Wait until the top three control panel lights go from white to striped before moving the RMS away from the payload. You are to move the RMS at least 24 inches away from the payload on the X axis. You have 15 minutes to complete the task.

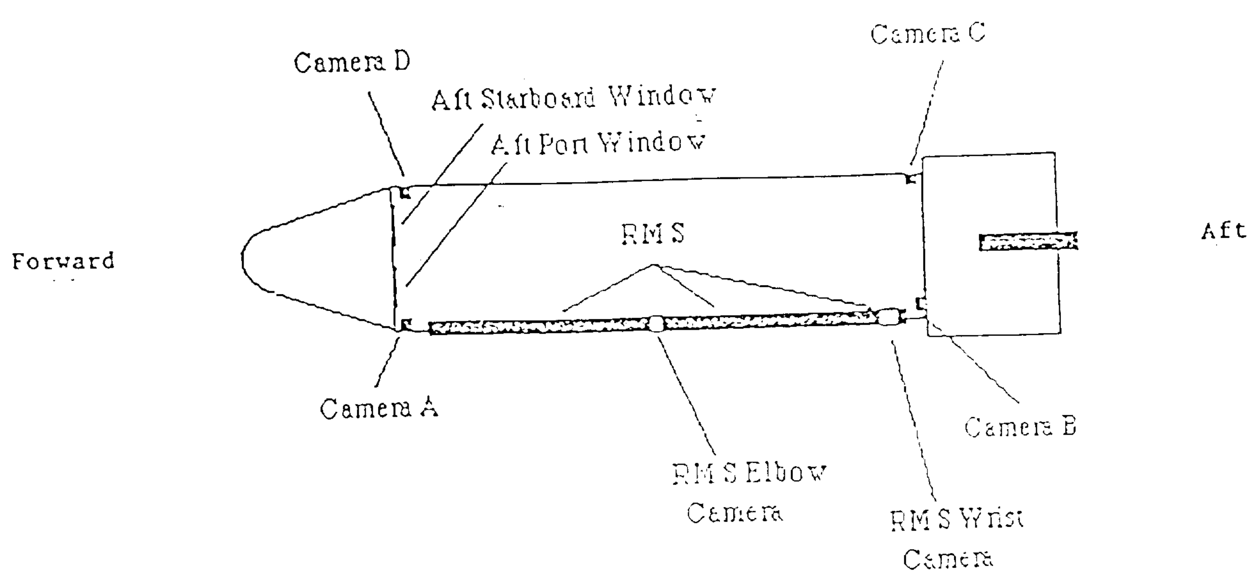
CAMERAS

Six cameras are used to view the RMS, payload, and payload bay: Cameras A - D, the Wrist Camera, and the Elbow Camera (see Figure 3). The name of the camera you are using appears at the upper left corner of the window.

To change a camera in a particular window, move the red arrow (via the computer mouse) to that window and press the control box button of the desired camera. With the exception of the wrist camera, you can move the cameras to show different views (including zooming in for close ups shots).

You can move or select any camera. However, you must have Camera B and Camera C set in its original position (straight ahead with the yellow guide post in full view) when the payload is being lowered into the payload bay. Furthermore, you will be required "cross cameras views" immediately after the payload levers come between the guide posts. To cross camera views, move Camera B so that it shows a view of the opposite guide post. Then, move Camera C so that it shows a view of it's opposite yellow guide post. Positioning these cameras in this way offers you a better perspective when stowing the payload.

Figure 3



## RMS SPEED

Key C on the keyboard sets the RMS in coarse mode. It lets the RMS move fast. Press key V on the keyboard to engage in vernier (pronounced vernyay) mode. Vernier moves the RMS slowly. Vernier mode is useful when you have to make precise movements.

## DISPLAYS

There are three LED displays (the three rectangles with red numbers inside) on the control panel. These indicators provide information on the end effector location and angle for each joint.

## DIALS

There are three dials on the control box that you should become familiar with. These dials operate important functions of control panel.

<u>Mode</u>
The Mode Dial is the top left dial next to the control box. For the purposes of our task, you will select End Effector Mode. End effector mode moves the RMS with the end effector as the point of origin for all RMS movements. To select end effector mode, turn the dial on the control box until the control panel Mode dial points to "End Effector". Then press the Enter button (located on the control box). Make sure that the End Effector light is glowing on the control panel before operating the RMS.

<u>Parameter</u>
The Parameter Dial is right below the mode dial. The dial provides you with information about the RMS. For our purposes, Position X/Y/Z, and Joint Angle are the most important to you. Turning the dial to Position X/Y/Z indicates (in inches) the position of the end effector from the orbiter's nose. To determine the angle of a particular joint, turn the dial Joint Angle. Then, use the Joint dial to choose the desired angle.

<u>Joint</u>
The Joint Dial is right below the parameter dial. It is used to select joint angle data. To determine a joint angle (e.g., wrist roll), turn the parameter dial to joint angle and then turn the joint dial to the desired joint (wrist roll).

## POTENTIAL PROBLEMS

Singularity occurs when you very close to reaching a joint constraint. That is, your close to reaching the angle's full extension. When singularity occurs, an alarm will ring and the Singularity light will glow on the control panel. Turn the alarm off by pressing the Master Alarm button on the control box. You can still move the RMS at a greater angle but be aware you may reach the limit of the RMS. For our purposes, it is best to find another route to your destination.

Reach limit occurs when you have reached a joint constraint. For example, try extending your elbow all the way. Unless you're double jointed you can just go so far before you can't move you're elbow anymore. If you continue to move the RMS in the same direction after attaining reach limit, the RMS will automatically lock up. You will not be able to operate the program. AVOID GETTING THE RMS INTO REACH LIMIT.

PERFORMANCE RULES

There are numerous performance rules for people to follow when operating the RMS. We don't expect you to remember all of these rules. They are intended to guide your performance and will be available for you to review at any time. Violations of any rules will be counted as errors. They rules are:

1. Do not get into singularity
2. Do not lock up the RMS.
3. Do not move any part of the payload through the payload bay.
4. Do not move any part of the payload through the guide posts.
5. Do not move any part of the payload through the notch walls.
6. Do not move any part of the payload through the bottom of the notch.
7. You must have the levers rest on the bottom of the notch.
8. Do not stow the payload incorrectly by having the payload's embedded bar levers off center (i.e., only one lever is resting on the set of notches).
9. Do not touch the payload with the end effector.
10. Do not engage in EE Auto mode from too far a distance.
11. Do not move the end effector with the payload before the top three indicator lights change from striped to white.
12. Do not move the end effector away from the payload before the top three indicator lights change from white to striped.
13. Do not stow the payload in a different area of the payload bay.
14. Do not overshoot the payload when trying to grapple.
15. Do not overshoot the guide posts when stowing.
16. Do not back up.
17. Do not overshoot a desired joint angle.
18. Engage in vernier mode when the levers are in sight of the guide posts with Camera B or Camera C.
19. Do not press a wrong button on the control box.
20. Do not press a wrong button on the joystick.
21. You must move Camera B or Camera C back to its original location as the payload is being lowered into the payload bay.
22. You must move Camera B or Camera C so that it shows the guide post on the other side of the bay as soon as the payload levers are between the guide posts.
23. Do not move the controls before engaging in end effector mode.

24. Do not engage in any mode other than end effector mode.
25. Do not move the joystick and the translator at the same time.
26. Do not operate the RMS and operate the cameras at the same time.
27. You are to move the RMS at least 24 inches away from the payload on the X axis.

## SUMMARY

In summary, your task is to:

1. Start the program by
    a) turning the Mode dial to End Effector
    b) pressing the Enter button on the control box
2. Move the RMS to the payload.
3. Grapple the payload.
4. Move the payload to the payload bay.
5. Stow the payload in the payload bay.
6. Move the RMS so that it is at least 24 inches away from the payload on the X axis.
7. Steps 1 - 5 are to completed within 15 minutes.

You will perform the task several times. Following each task cycle you will answer several questions.

Five templates are available for your use. The templates summarize basic operations described above.

Appendix G.

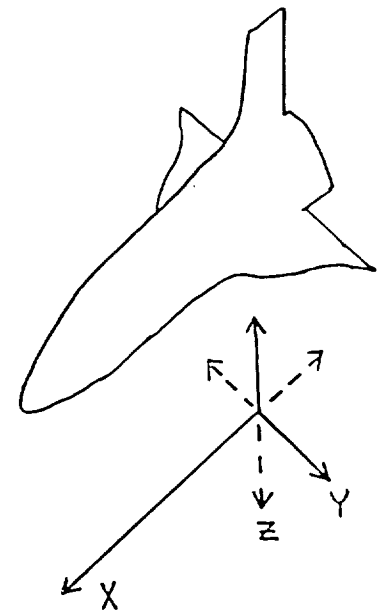
**TEMPLATE 1**

Moving the RMS End Effector with the Translator

1. Push in to go forward. (X axis)
2. Pull to go back.

3. Move left to go left. (Y axis)
4. Move right to go right..

5. Move up to go up. (Z axis)
6. Move down to go down.



**TEMPLATE 2**

Moving the RMS End Effector with the Joystick

1. Pitch means to rotate around the Y axis. Pull (push) the joystick to pitch up (down).

2. Yaw means to rotate around the Z axis. Twist the joystick left (right) to go yaw left (right).

3. Roll means to rotate around the X axis. Move the joystick left (right) to go roll left (right).

**TEMPLATE 3**

## Engaging and disengaging End Effector auto mode

ENGAGE

1. Press the EE Auto Mode button on the control box.
2. Pull the trigger on the joystick.

DISENGAGE

1. Locate the three buttons near the top of the joystick.
2. Press the far left button.

**TEMPLATE 4**

Camera Selection and Movement

SELECTION

1. Use the mouse to move the red arrow into the window that contains the camera that you want to change.
2. Select the new camera by pressing the appropriate camera button on the control box.

MOVEMENT

1. Tilt the camera up (down) by pressing and holding the Tilt Up (Tilt Down) button on the control box.
2. Pan the camera left (right) by pressing and holding the Pan Left (Pan Right) button on the control box.
3. Zoom the camera in (out) by pressing and holding the Zoom In (Zoom Out) button on the control box.

REMINDER

1. Make sure that Camera B and Camera C show the yellow guide posts in front of them when you are about to lower the payload into the payload bay. Make sure that they are aimed at the guide posts at the opposite end of the payload bay when the levers are between the guide posts.

**TEMPLATE 5**

Using the Dials

MODE

1. Select the mode that you desire by turning the Mode dial on the control box while watching the mode dial on the control panel.
2. Press the Enter button on the control box.
3. Make sure the light for that mode lights up on the control panel.

PARAMETER

1. Select the parameter by turning the Parameter dial on the control box while watching the Parameter dial on the control panel.

JOINT

1. Turning the Parameter dial to Joint Angle.
2. Select the joint rotation by turning the joint dial on the control box while watching the Joint dial on the control panel.