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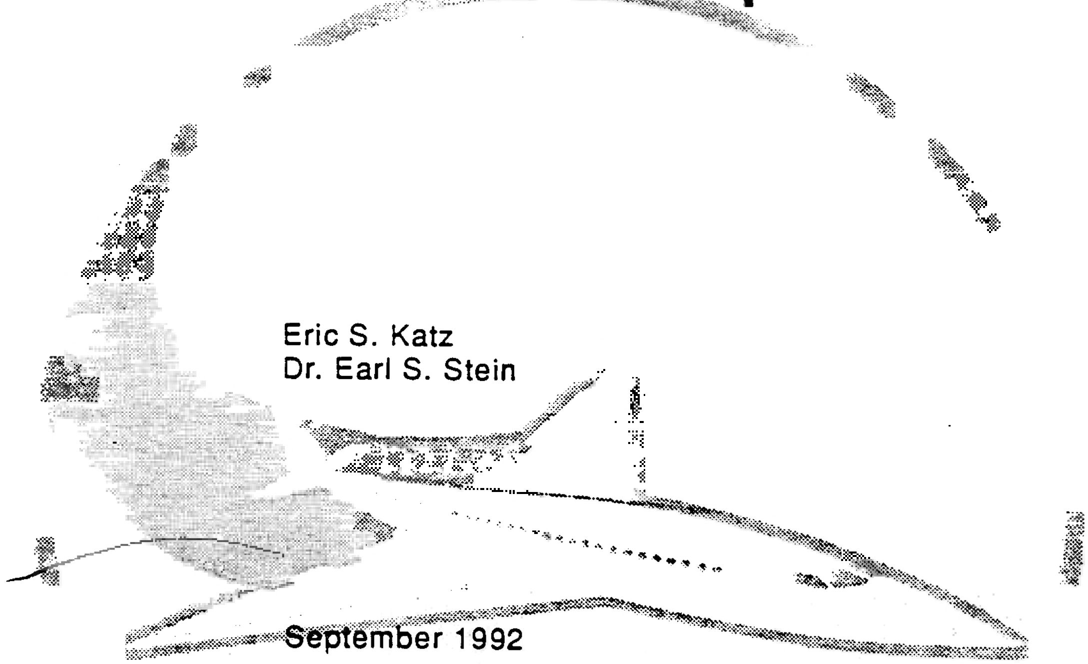
**FAA Technical Center**
Atlantic City International Airport
N.J. 08405

# Prototype Stop Bar System Evaluation at John F. Kennedy International Airport



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Final Report



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16. Abstract

A prototype stop bar system was installed and evaluated at John F. Kennedy International Airport. The purpose of the year-long evaluation was to gain operational experience on the use of a stop bar system and how it could possibly impact the air traffic system. To determine the effectiveness of the stop bar system, data were collected from both user pilots and air traffic controllers. Results of the pilot data indicate that the system is somewhat effective in preventing inadvertent runway incursions, but not as effective as stop bar systems operating at European airports. Results of the air traffic controller data indicate that although the majority of the controllers felt that stop bars are conceptually a good idea, almost all of them agreed that the system was not acceptable, especially when combined with the local control position at moderate to high traffic load.

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TABLE OF CONTENTS

## LIST OF ILLUSTRATIONS

Figure



## LIST OF TABLES

Table

# EXECUTIVE SUMMARY

The first United States stop bar system was installed and evaluated at John F. Kennedy International Airport. The purpose of the installation was to help prevent inadvertent runway incursions, and to gain operational experience on the use of a stop bar system and how it could possibly impact the air traffic system.

The stop bar system consists of 15 individual stop bars. Each stop bar contains red and green elevated and inset lights that do not conform to the International Civil Aviation Organization (ICAO) standard stop bar configuration. The stop bars are radio remote controlled from the control tower through the use of a mimic panel operated by air traffic controllers.

The year-long evaluation of the stop bar system included the collection of data from both user pilots and air traffic controllers. In addition, maintenance records of the stop bar system were recorded. Results of the pilot data indicate that the system is somewhat effective in preventing inadvertent runway incursions, but not as effective as stop bar systems operating at European airports. Results of the air traffic controller data indicate that although the majority of the controllers felt that stop bars are conceptually a good idea, almost all of them agreed that the system was not acceptable, especially when combined with the local control position at moderate to high traffic load.

# INTRODUCTION

## BACKGROUND.

Runway incursions can be defined as the unauthorized presence of an aircraft or vehicle on an active runway. In an effort to prevent runway incursions, the Federal Aviation Administration (FAA) and the Port Authority of New York and New Jersey, with support from the aviation industry, developed a plan for installing and testing a prototype stop bar system to protect runway 4L-22R at John F. Kennedy International Airport (JFK). The stop bar system consists of controllable red and green lights. These lights are located adjacent to the runway holding position markings at taxiway/runway intersections. When the controller issues a verbal clearance to either cross or enter an active runway, he/she activates the system which changes the stop bar lights from red to green. This provides pilots with a visual confirmation of the controller's verbal clearance and is intended to prevent runway incursions.

The Port Authority was given the responsibility to design and install the system, and funding was provided by both the FAA and the Port Authority. The FAA Technical Center was responsible for conducting the evaluation of the stop bar system. Before the evaluation began, equipment modifications were necessary to improve system reliability and operational capability. Subsequent to these modifications, the 1-year, in-service evaluation was initiated. In conducting the evaluation, particular attention was directed toward obtaining pilot and controller opinion of the system's effectiveness.

## PURPOSE.

The purpose of the stop bar installation was to help prevent inadvertent runway incursions, and to gain operational experience on the use of a stop bar system and how it could possibly impact the air traffic system. In addition, the results of the stop bar evaluation will be used as guidance towards developing a United States stop bar standard.

## OBJECTIVE.

This evaluation was directed specifically towards determining:

1. How effective the stop bar system is in preventing inadvertent runway incursions.

2. How the stop bar system compares to stop bars installed at other (European) airports.

3. If the system is acceptable to air traffic controllers.

## TEST METHODOLOGY.

The JFK stop bar system was evaluated from both a user pilot and air traffic controller perspective. Pilot opinion of the stop bar system was obtained through the distribution of questionnaire forms. After the pilots had gained sufficient experience with the stop bar system's operation, they were asked to complete the questionnaire forms. Controller opinion of the stop bar system was obtained by distributing questionnaire forms and conducting controller interviews. The recorded data were then analyzed to determine the effectiveness of the stop bar system.

## SYSTEM DESIGN

The prototype stop bar system consists of fifteen individual stop bars. Thirteen of the fifteen stop bars are located on taxiways that intersect with runway 4L-22R, and two stop bars are located on taxiways that intersect with runway 13R-31L (see figure 1). Each of the fifteen stop bars consists of two red and two green L-862 elevated edge lights, and three modified L-850B in-pavement fixtures. The elevated lights are 115 watts each and were included in the design because of the possibility of the in-pavement stop bar lights being obscured from the pilots view by snow/ice or by a significant cockpit cutoff angle. In addition, elevated stop bar lights comply with an International Civil Aviation Organization (ICAO) recommendation.

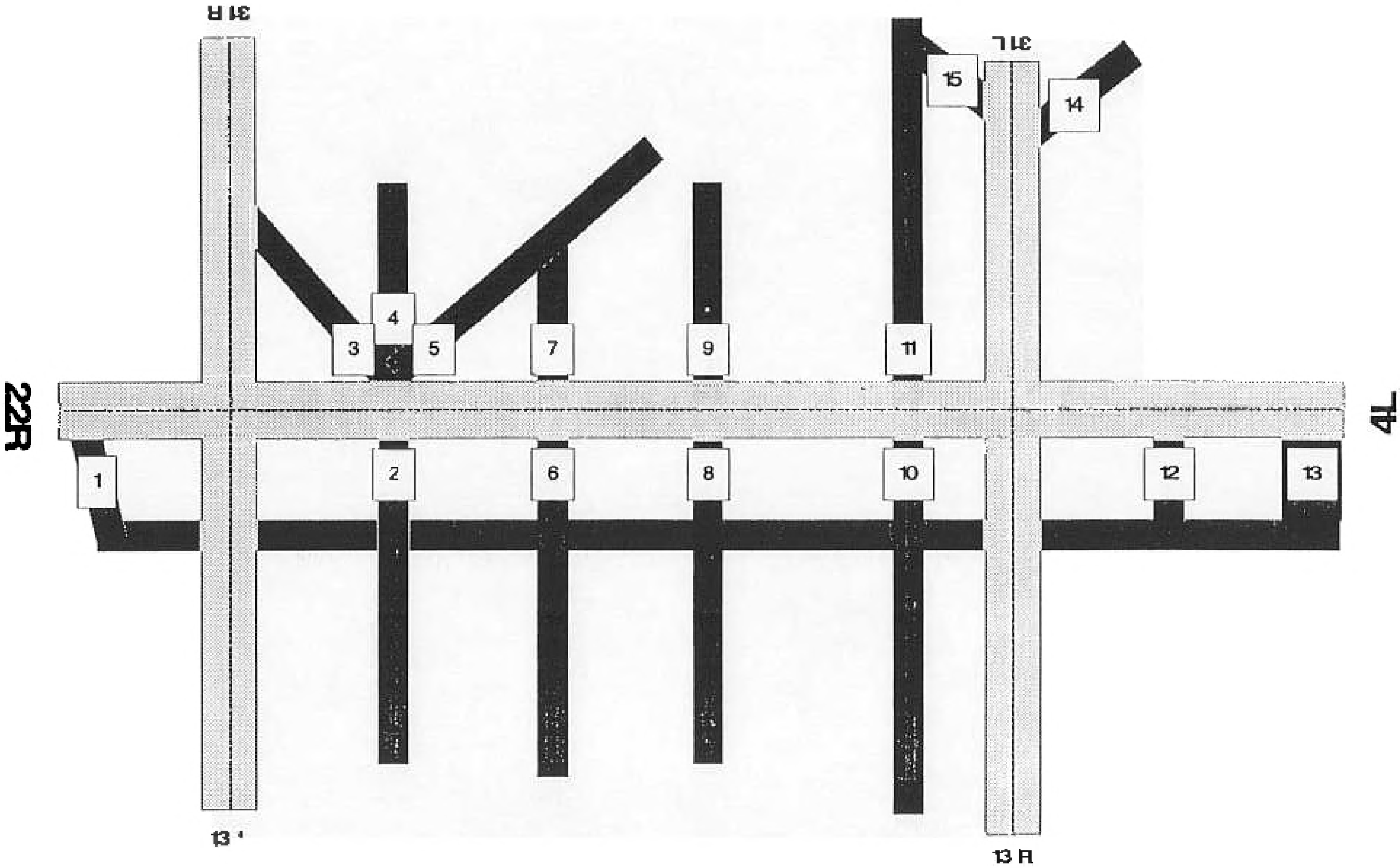
The in-pavement light configuration was selected to permit the use of the three existing hold bar lights that had been previously installed per Advisory Circular 150/5340-19, "Taxiway Centerline Lighting Systems." The in-pavement fixtures each have two apertures facing an approaching aircraft, one containing a red lens and one containing a green lens. The stop bar design includes the green "confirmation lights" colocated with the red lights.

The visual presentation of an individual stop bar appears as either five red lights (see figure 2), or five green lights (see figure 3). When the air traffic controller elects to switch the stop bar from red to green, the red lamps are extinguished and the green lamps are illuminated. As a fail-safe feature, the lights default to red if a system problem should occur. Photographs of the red and green inset lights are shown in figure 4. Photographs of the red and green elevated lights are shown in figure 5.

A stop bar mimic panel is located in the tower cab and is operated by an air traffic controller. The panel features a display of the runway/taxiway intersections where stop bars are installed, light emitting diode (LED) indicators to report stop bar light status, and pushbuttons to operate the system (see figure 6).

For stop bar control and monitoring, a radio remote control system was selected in lieu of installing control wires. A main terminal unit, located in the tower, transmits a controller activated signal that originates at the mimic panel. A remote terminal unit, located at each stop bar location, receives this signal and changes the color status of the stop bar. In addition, the remote terminal unit transmits a signal back to the main terminal unit signifying that the change of color status has occurred at the stop bar. This change is then reflected by the status lights on the mimic panel. In addition, an electrical/fixture subsystem, that includes power converters, high voltage switches, and electrical fixtures, is located at each taxiway intersection.

# JFK STOP BAR SYSTEM




FIGUR LOCATION OF 15 STOP BAR

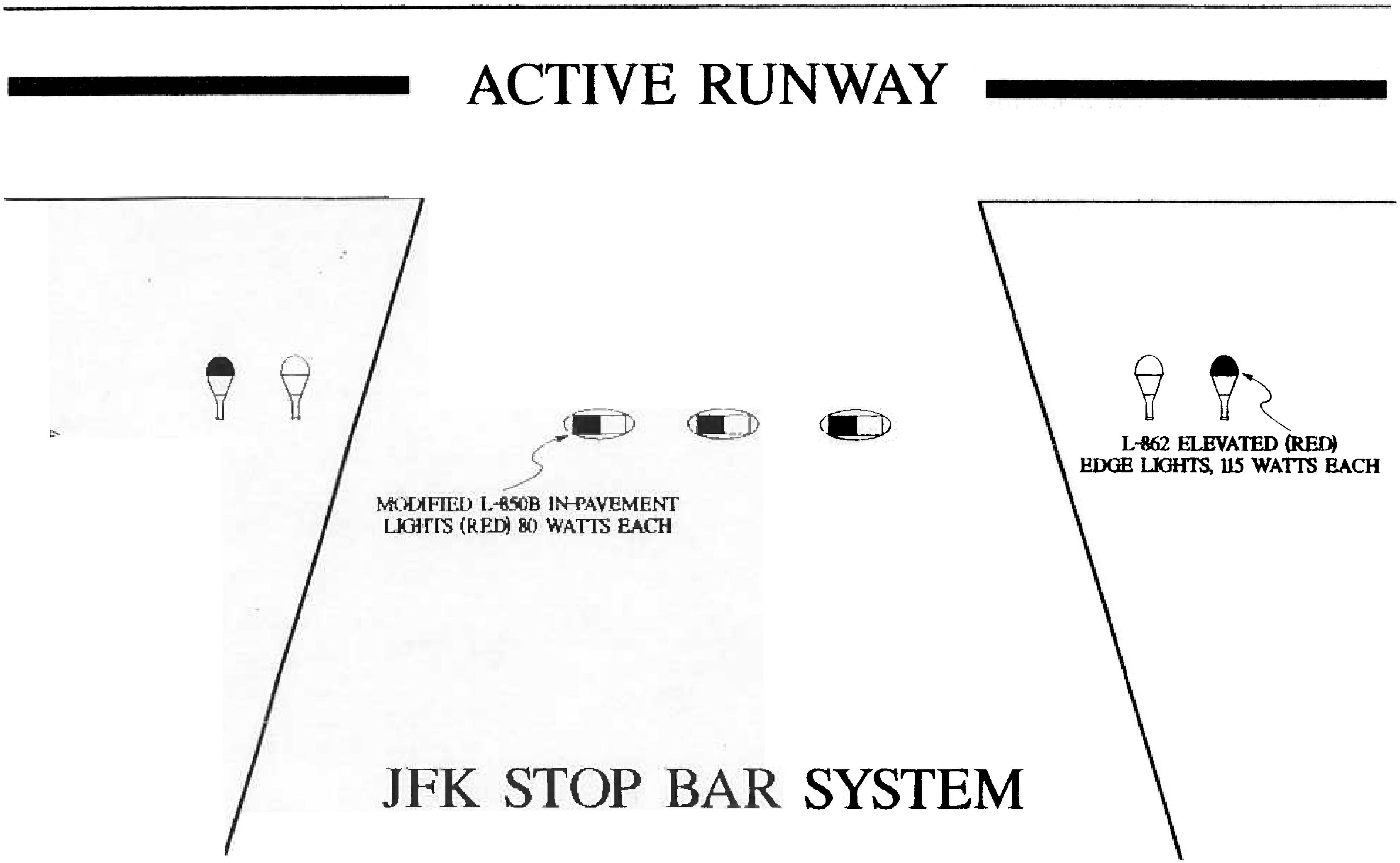



FIGURE 2. RED STOP BAR VISUAL PRESENTATION

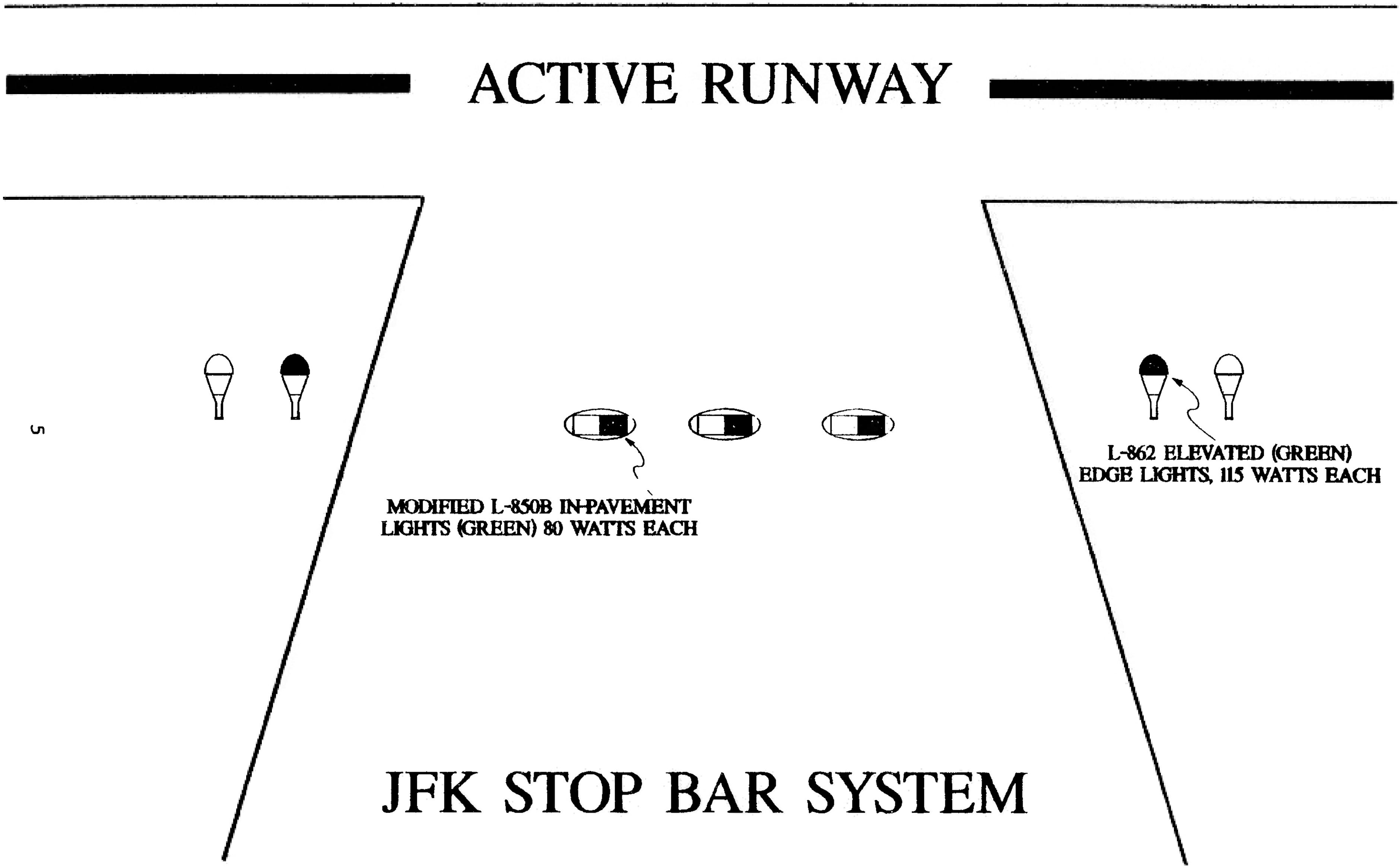



FIGURE 3. GREEN STOP BAR VISUAL PRESENTATION

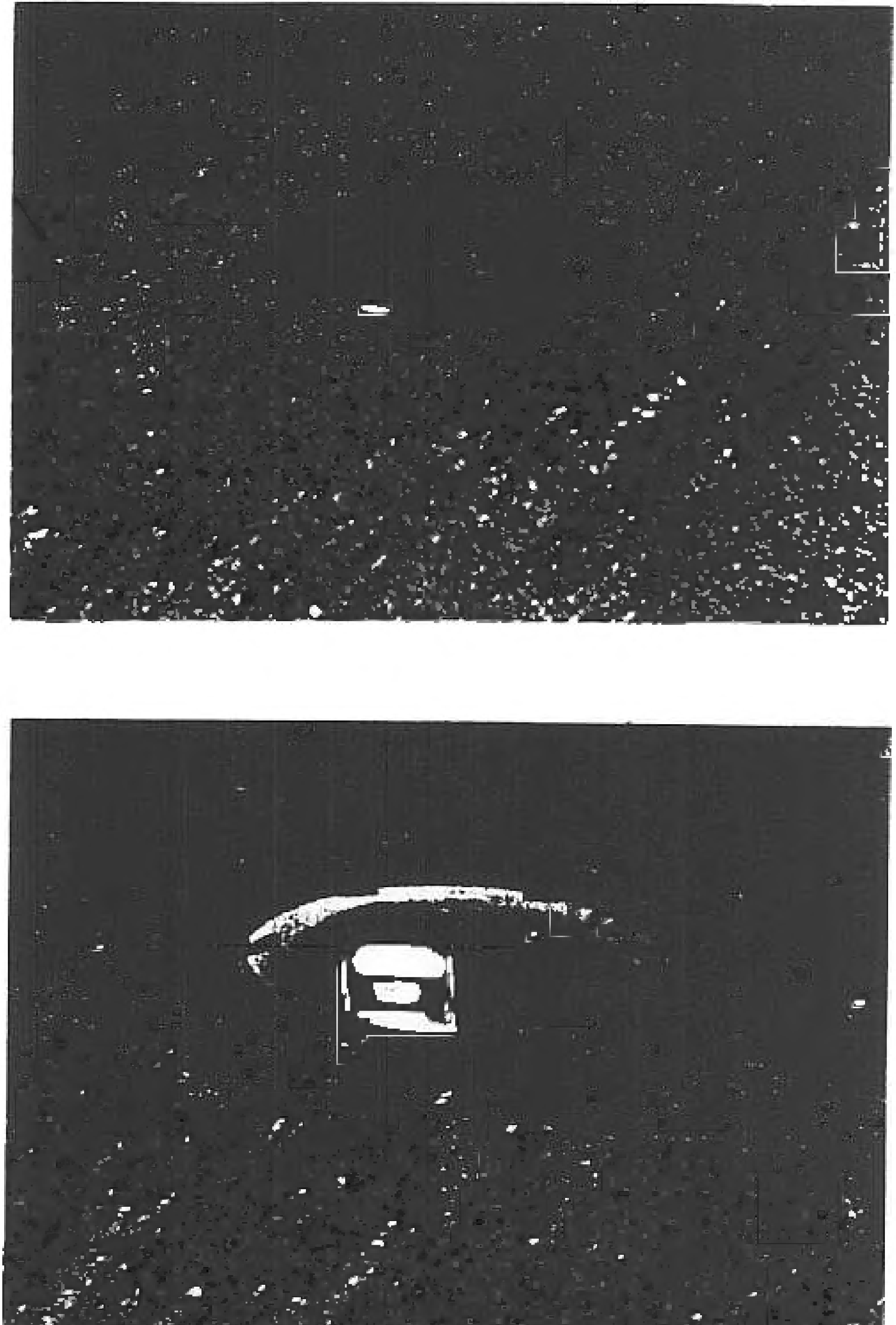
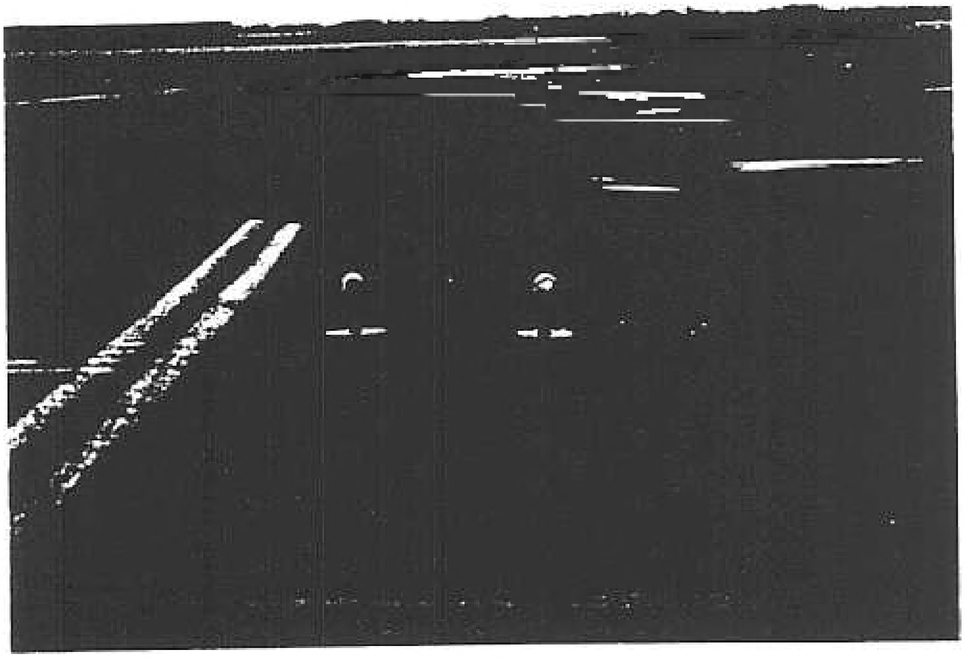
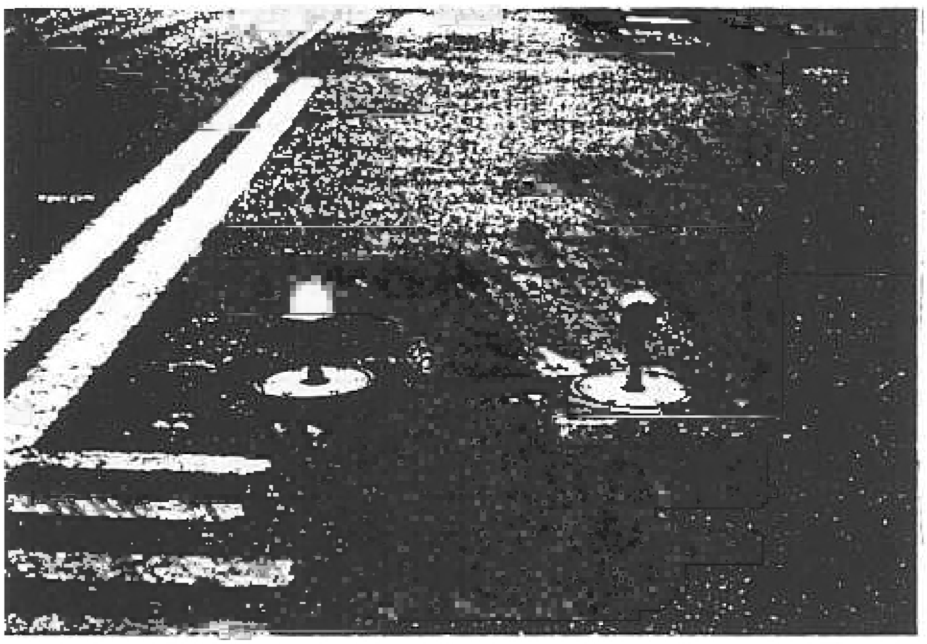


FIGURE 2. AND GREEN INSET STOP B/





[illegible] ND GREEN ELEVATED STOP BAR LIGHTS

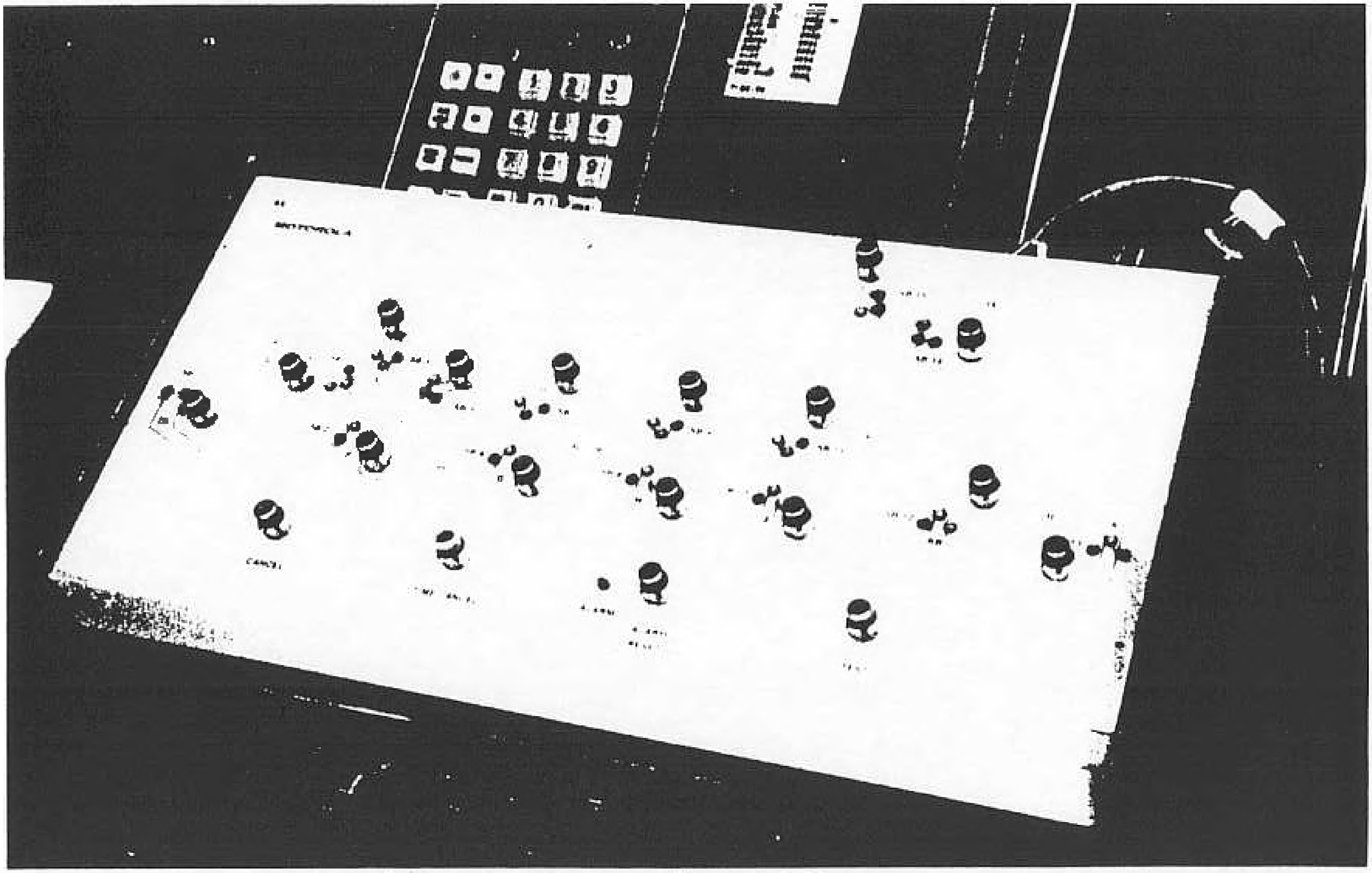


FIGURE STOP BAR MIMIC PANEL

The system is monitored and is designed to indicate the following system malfunctions: remote terminal unit failure, power failure of a stop bar converter, failure of a stop bar to change color status, or failure of a power circuit. Any change of stop bar color status caused by a power failure will result in flashing amber and red lights on the controller's mimic panel.

## SYSTEM OPERATION

The stop bar system was installed and operated to increase the visibility of the mandatory runway holding position and to confirm air traffic verbal clearances to either enter or cross a runway. The stop bars are clearly intended to serve only as a visual confirmation of the governing oral command.

During the year-long evaluation, the stop bar system was operated during daytime and nighttime Visual Flight Rules (VFR) and Instrument Flight Rules (IFR) conditions. Regardless of the visibility conditions, the stop bar lights were operated at an intensity setting one step brighter than the associated taxiway lights.

The entire stop bar system is operated from the air traffic controller's mimic panel. The stop bar and mimic panel lights are normally red. When a verbal clearance to either enter or cross the runway is issued, an air traffic controller operates the pushbuttons associated with that stop bar. The indicator lights on the mimic panel change from red to green as an indication that the airfield stop bar lights have also changed from red to green.

Changing the lights back from green to red is accomplished automatically by a timer. The indicator lights on the mimic panel switch from green to red, again as an indication of the stop bar color change. The timers are set for 20 seconds, but they can be easily set to a different time interval if so desired by air traffic control. The 20-second interval was decided upon after field tests and observations of aircraft crossings.

If the stop bar controller determines that he/she needs to extend the green light operation, this can be accomplished by depressing the stop bar pushbutton again. When the green lights of a stop bar are illuminated and the timing cycle is in progress, activation of the pushbutton for that particular stop bar will restart the timing cycle, allowing the green lights of that stop bar to remain illuminated for an additional full 20-second timing cycle.

The automatic reset of a stop bar from green to red may be overridden by the stop bar controller, resulting in the stop bar remaining green indefinitely. This is accomplished when the controller depresses a "time cancel" pushbutton after depressing the stop bar pushbutton. The stop bar and mimic panel indicator light will remain green until the "cancel" pushbutton, followed by the stop bar pushbutton, is depressed. This action results in an immediate return of the stop bar and indicator light to red.

If a pushbutton is depressed inadvertently, the operation can be cancelled by depressing the "cancel" button followed by the stop bar button in question. The stop bar will reset to red immediately and will be reflected by the appropriate red light illuminating on the mimic panel.

## SYSTEM EVALUATION

FIELD EQUIPMENT.

Before the full-scale evaluation of the stop bar system could be initiated, several modifications to the system had to be performed to eliminate a number of technical problems. The most critical difficulties were:

1. Frequent occurrences of actual and false system malfunction alarms resulting from the effect of spurious radiations from radio frequency (RF) sources (communications transceivers, navigation transmitters, etc.) on, and in the vicinity of, the airport.

2. Air traffic controller dissatisfaction with system response times in controlling stop bar signal activation when issuing clearances for aircraft and vehicles to enter or cross the protected runway. Operational air traffic control procedures at JFK frequently required that controllers clear several aircraft, in succession, to cross the protected runway at different taxiway intersections. Verbal crossing clearances, requiring multiple stop bar activations, were issued sequentially with only 10-second intervals between each clearance. The stop bar radio control system was unable to respond quickly enough to these multiple commands for activation after three successive clearances had been issued. Response times (i.e., the interval between tower stop bar activation and signal color change in the field) were within the air traffic control requirement of less than 3 seconds for the first three successive activations, but then control system performance degraded to extended activation response times of greater than 7 seconds for subsequent clearances. Pilots, having to wait this prolonged period of time for the stop bars to be extinguished, frequently queried the controllers by radio, resulting in tower frequency congestion and increased controller workload.

Remedial efforts were successful in overcoming the spurious RF radiation problem through software and hardware changes to the radio remote control system.

To address and correct the slow system response problem, the following system component modifications were completed:

1. Changes to control system computer software logic and command sequences.

2. Substitution of individual time-out devices in the field stop bar site locations in place of a central time-out unit in the main computer.

Activation time-delay tests were conducted at JFK, once the alterations had been accomplished, to verify that the air traffic control operational requirements had been attained. The results of these tests were fully successful, and the stop bar system was placed into operation for in-service testing on March 25, 1991.

In addition to the system modifications, provisions were made for a 1-year "parts and labor" maintenance contract for the JFK stop bar system. The time period for this maintenance contract addition was from March 25, 1991, to March 24, 1992.

The field equipment, specifically the stop bar lights, were evaluated for a period of 1 year by airline pilots operating at JFK. After the pilots were given a chance to gain experience with the operation of the stop bar system, pilot questionnaire forms were distributed to the major domestic and international carriers. The questionnaire forms were designed primarily to gain pilot insight into how effective the stop bar system is in preventing inadvertent runway incursions, and how the system compares with stop bar systems operating at European airports.

TOWER EQUIPMENT.

The tower equipment, specifically the operation of the stop bar mimic panel, was evaluated from the perspective of the air traffic controllers. The stop bar system evaluation progressed through a series of phases during which the local controller would accept increasing levels of responsibility for operating the stop bar equipment in addition to his/her normal duties. Controller input was collected using two human engineering evaluation techniques.

Technique A - Controller response to a controller input questionnaire:

The training staff and management of JFK tower, in consultation with the local union, established the standards under which the stop bars would be employed and who would operate them. The test officially began on March 25, 1991. It was desirable, however, to collect data prior to that date in order to establish a baseline of information and perceptions. The goal agreed upon with tower personnel was to collect input from controllers working the local control position and, when implemented, the stop bar position. Responses would only be requested during the time period of 1700-1900 local time each day. This was done so that control personnel would not burn out too soon in terms of compliance with the evaluation effort. While it was hoped that everyone working those positions at those times would complete the feedback form, it was understood that compliance was voluntary and that less than 100 percent response rate would occur.

The controller input questionnaire (see appendix A) was constructed and staffed through union and management at the facility prior to implementation. No identifying information was collected, and the respondent was asked to make up a 4-digit alpha numeric code which he/she could use consistently so that the responses could be tracked over time. The questionnaire asked the controller to make three numerical estimates on 10-point scales: traffic volume, workload, and busyness. There was also the opportunity for the controllers to write any comments that might clarify their responses.

During the time of the test, the tower provided the research team with copies of the traffic log sheets for every day that controllers completed the questionnaires.

The test itself was to proceed in three phases. Counting the baseline data collection as a separate phase for research purposes, there were four successive phases. The baseline data collection began in February 1991 and proceeded for 1 month until the stop bars became operational on March 25. During this period, only local and assistant local controllers were asked to complete the questionnaire. (The title of "assistant local controller" was to undergo some transition during the course of the study and may be referred to elsewhere as the "tower cab coordinator.") The second phase involved a period from March 25 through the end of May during which a controller was dedicated to the stop bar mimic panel operation and had to coordinate his/her activities with those of other positions. During this period, both stop bar and local controllers were asked to fill out the questionnaire. The next phase of the test involved a transition of operational control where there was a stop bar person available but not necessarily assigned to the stop bar mimic panel. During this period, sometimes there was a dedicated operator and sometimes there was not. These transitional changes explain in part why there were considerable differences in response rates across the phases. The final phase of the test began on October 1, 1991, and continued until March 25, 1992, at which time the stop bar system was turned off and the evaluation ended. During the final phase, the local controller was theoretically responsible for the operation of the stop bar mimic panel in addition to his/her other duties. Direct observations of tower operations indicated that this task was sometimes shared by the assistant local controller.

Compliance with the controller questionnaire program in the final phase of the test was, unfortunately, very limited. Only four questionnaires were returned, which were not enough to warrant further analysis. In an effort to gain additional controller input as the evaluation was drawing to a close, a second human engineering evaluation technique was employed.

Technique B - Controller response to an interview program:

The interviews were conducted based on the assumption that given a face-to-face opportunity where anonymity was guaranteed, controllers would be willing to talk about both the strengths and weaknesses of the stop bar system, which they had experienced during the past year.

While the numbers have varied somewhat, there are currently 29 controllers, of which 5 are developmental, at JFK. There are 4 staff personnel and 4 first line supervisors, all of whom are full performance level controllers. An arbitrary goal of 20 interviews was established. It was believed that this would well represent the perceptions of the personnel in the tower. Three persons were specifically excluded from the potential sample. These included the tower manager, his deputy, and the staff person who had been charged with coordination of the stop bar test from the beginning.

Twenty-two interviews were completed. These included 3 staff personnel, 3 first line supervisors, and 16 controllers of which 3 were developmental. The range of interviewee's experience in air traffic control was from 2 years for the developmental controllers and up to 35 years for one supervisor. The median experience of all participants was 9 years. All personnel had worked the local control position along with the stop bars, and most had also worked the dedicated stop bar position during an earlier phase of the test. All personnel participated voluntarily and were promised anonymity. No records were maintained of their names, and participant numbers were assigned arbitrarily. All bargaining unit employees were further informed that the process and the specific questions to be asked had been coordinated with their union.

The interviews were conducted between March 23 through March 25, 1992, at JFK tower. Controllers and supervisors were alerted to the presence of the interviewer, and they came in as their control duties permitted. The interviews were based on a semi-structured format. Each interview lasted from 20 minutes to 1 hour depending on how much information the controller felt he/she had available.

The primary purpose of the first page of the interview program was to establish a frame of reference in the controllers thinking. The focus of this was questions concerning the process of working traffic from the tower with an emphasis on local control. Command and control issues and communication patterns were discussed. During the survey portion of the human factors review, controllers generally did not indicate that they were overloaded when someone else was working the stop bars. The interviewer had observed some communication issues raised by the presence of the stop bars and wanted the respondents to be thinking about how information was shared and exchanged among those in the tower. As it turned out, there were communication changes that occurred even during the period of dedicated stop bar controllers. However, of principle concern was the impact on the local controller when he/she had the additional responsibility of working the stop bar control system and monitoring the status of the lights on the field surface. The second and third pages of the interview program were centered directly on the stop bar program and its impact on the team operation in the tower cab.

## RESULTS

### EQUIPMENT RELIABILITY.

The maintenance contract terminated on March 24, 1992, at which time the in-service testing program at JFK also was terminated. Insofar as can be determined, all system components were serviceable, and the stop bar system was operational at this time.

It is somewhat surprising that, during the period of the maintenance contract, the majority of malfunctions involved failures of components in the power/converter units. Almost half of the service calls (6/14) required replacement or repair of the K-1 contactor, while the remainder of the service calls were concerned with "one-time," nonrecurring repairs or replacement of separate and distinct components (pushbuttons, connectors, etc., appendix B).

The basic radio remote system was remarkably trouble-free, which might have been expected since virtually all components were "off-the-shelf" manufactured items. If the radio control system can be said to have exhibited any fault at all, it would be that of slow response to activation commands, as discussed earlier in this report. This "fault," however, must be recognized as resulting from an inadequate initial system design and equipment selection, and not from radio system component failures. Use of a "state-of-the-art" radio remote control system, irrespective of manufacturer, would probably provide satisfactory service.

PILOT QUESTIONNAIRE RESPONSES

As shown in figure 7, 59 percent of the airline pilots felt that the stop bar system is very effective in preventing inadvertent runway incursions, and 39 percent agreed that the system is marginally effective. As shown in question 2, 85 percent of the respondents stated that the system display is sufficiently distinctive to prevent confusion with other airport lighting systems. An overwhelming majority of the pilots (94 percent) thought that the safety benefits of the stop bar system are sufficient to justify additional installations to protect runways at other major airports. In response to question 4, 62 percent of the pilots who have had experience with stop bar systems installed at European airports agreed that the JFK stop bar system was not as effective as the European systems. Thirty of the pilots specifically mentioned London - Heathrow as the airport with the superior system.

As evidenced in appendix C, airline pilots provided several very important comments regarding the effectiveness of the JFK stop bar system. Of particular note are the following pilot observations:

1. The stop bar system should be more distinctive. Specifically, the pilots agreed that the red stop bar lights would be more conspicuous if they were installed completely across the taxiway, as required by the International Civil Aviation Organization.

2. Pilots stated that the stop bar lights reverted back to red prior to the aircraft crossing the stop bar. It would appear from this comment that the 20-second time interval, during which the red stop bar lights are extinguished, is simply not long enough.

the "tower cab coordinator.") The second phase involved a period from March 25 through the end of May during which a controller was dedicated to the stop bar mimic panel operation and had to coordinate his/her activities with those of other positions. During this period, both stop bar and local controllers were asked to fill out the questionnaire. The next phase of the test involved a transition of operational control where there was a stop bar person available but not necessarily assigned to the stop bar mimic panel. During this period, sometimes there was a dedicated operator and sometimes there was not. These transitional changes explain in part why there were considerable differences in response rates across the phases. The final phase of the test began on October 1, 1991, and continued until March 25, 1992, at which time the stop bar system was turned off and the evaluation ended. During the final phase, the local controller was theoretically responsible for the operation of the stop bar mimic panel in addition to his/her other duties. Direct observations of tower operations indicated that this task was sometimes shared by the assistant local controller.

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JFK STOP BAR LIGHTING SYSTEM EVALUATION

AIRLINE PILOT QUESTIONNAIRE

1. How would you rate the effectiveness of this system in preventing inadvertent runway incursions?

Very effective: 48 (59%), Marginally effective: 32 (39%), Ineffective: 2 (2%)

2. Is the system display (red/green light bars) sufficiently distinctive to prevent confusion with other airport lighting systems?

Yes: 69 (85%)     No: 12

3. Are the safety benefits of this system sufficient to justify additional installations to protect runways at other major airports?

Yes: 78 (94%)     No: 5

4. If you have had experience with similar systems at other (European) airports, how would you rate the JFK system in comparison?

Better than: 4 (6%), Equal to: 23 (32%), Not as good as: 44 (62%), No experience: 11

European airport with better system: London-Heathrow 30 (42%)

5. Additional Comments: See Appendix C.

Type Aircraft____ Air Carrier____ Pilot (Optional) 83 TOTAL

Conditions: Day: 35     Night: 55     VFR: 33     IFR: 46     Low-Vis: 31

FIGURE 7. SUMMARY OF PILOT QUESTIONNAIRE RESPONSES

CONTROLLER RESPONSES - CONTROLLER INPUT QUESTIONNAIRE.

The following table describes the response rates for the one-page survey instrument:

TABLE 1. CONTROLLER RESPONSE FREQUENCIES

| | Phase | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| Responses | 45 | 115 | 39 | 4 |

Over the course of this study, 203 responses were received, and 199 were subsequently processed. The four questionnaires in the last phase were not statistically analyzed, but any comments at the end of the questionnaire were included in the qualitative data to be presented latter in this report. All questionnaires were administered anonymously. We asked the controllers to come up with a 4-digit code to identify themselves, and most complied with this request. However, when the responses were sorted on this code, 43 separate codes were employed. As of phase four, there were 29 operational controllers in the tower. Allowing for some transitions of personnel, it still appeared likely that some controllers used more than one code throughout the study. This may have been due to their failure to write down the code they had selected for themselves, or possibly to their desire to reduce the probability of identification. The codes do tell us that controllers varied considerably in terms of the frequency of their participation in the study, from as little as only 1 response to as many as 13 completed questionnaires. There were 14 controllers who responded 5 or more times during the entire test. Demographically, the controllers ranged in experience from 2 to 21 years in air traffic control with a mean of 6.08 years.

Summary Descriptive Statistics.

Table 2 provides the means or averages of controller responses to the three key questions in the survey during the various phases of the study. The final phase is not included due to the lack of data, and it will be dealt with by interview data provided in a latter section of the report. In addition to controller responses, the mean traffic counts for IFR traffic are also provided in table 2. These were computed by extracting the appropriate data from the official log sheets for tower activity. The column labeled "% Busy" in the table has been modified. The actual question asked the controller to estimate the percentage of time he/she was busy from 0 to 100 percent. The responses provided were divided by 10 in order to bring the resulting column into the same scale as the other questions on which responses were made to a 10-point scale.

The data are presented in table 2 according to the position the individual worked when doing the rating. Also the means for each question are provided at the bottom of the phase section in the row labeled grand mean. The positions labeled A through E in tables 2 and 3 refer to the following: A=Local Departure; B=Local Arrival; C=Local Combined; D=Assistant Local; and E=Stop Bar Controller. The frequencies of responses in each of these positions were as indicated in table 3.

TABLE 2. MEAN QUESTIONNAIRE RESPONSES BY PHASE AND POSITION

| Pretest Phase 1 | Position Worked | Traffic Volume | Workload Estimate | % Busy Estimate | IFR Traffic |
|---|---|---|---|---|---|
| | A | 6.25 | 5.88 | 6.50 | 58.88 |
| | B | 5.50 | 5.00 | 6.00 | 54.00 |
| | C | 4.64 | 4.70 | 3.88 | 46.52 |
| | D | 1.00 | 1.00 | 1.00 | 38.00 |
| Grand Mean | | 4.89 | 4.84 | 4.39 | 48.91 |
| Phase 2 | A | 6.16 | 4.47 | 5.05 | 54.74 |
| | B | 5.08 | 5.00 | 4.58 | 54.33 |
| | C | 5.26 | 5.21 | 4.33 | 46.24 |
| | D | 3.18 | 3.18 | 3.09 | 51.00 |
| | E | 3.31 | 2.76 | 2.17 | 38.11 |
| Grand Mean | | 4.69 | 4.25 | 3.81 | 47.06 |
| Phase 3 | A | 6.00 | 5.33 | 5.00 | 63.50 |
| | B | 6.33 | 6.67 | 6.00 | 66.00 |
| | C | 3.74 | 3.48 | 2.96 | 38.04 |
| | D | 4.33 | 3.33 | 3.33 | 36.33 |
| | E | 5.00 | 4.00 | 3.75 | 57.50 |
| Grand Mean | | 4.46 | 4.05 | 3.62 | 45.97 |

TABLE 3. RESPONSE FREQUENCIES BY POSITION

| Position | Frequency |
|---|---|
| -- | 4 |
| A | 32 |
| B | 17 |
| C | 99 |
| D | 16 |
| E | 32 |

These frequencies are relevant from a number of perspectives. First it is clear that there was considerable unevenness in the return rate from the different positions in the tower cab. Part of this is explained by the fact that the cab is ordinarily configured to meet the needs of the situation. Also, there was no stop bar operator during the pre-test period that is referred to here as phase 1. Second, we can use these frequencies latter for analyses which judge the probabilities that personnel will respond to the situation in some systematic manner which may be driven by chance or the environment. This will be described latter.

As one examines the table of means for controller responses across the phases, there are several observations to be drawn. While there appears to be some variability across positions, overall there does not seem to be any noteworthy changes occurring in busyness, workload, or time occupied as the stop bars were phased in after the baseline data collection. Of course, this result may have been confounded by what appears to be an overall decline in IFR traffic during the period covered. A number of controllers would mention this later during the interviews and attributed it to seasonal changes and the impact of the Gulf war on commercial travel in general.

The next approach to analyzing the data collected in the longitudinal portion of the this study involved the intercorrelation of the questionnaire variables along with both demographic information (years in air traffic control and controller status) and actual traffic volume taken from the tower logs. The following coding conventions were employed in order to accomplish this analysis: The position occupied was recoded from letters A through E to numbers 1 through 5. This was a matter of convenience, and subsequent correlations are considered only indicative rather than conclusive. The presence or absence of stop bar operations were coded as 1 yes and 2 no, a dichotomous variable. Controller status was coded as 1 full performance level (FPL) and 2 developmental (DEV), another dichotomous variable. All other variables in the correlation matrix were continuous and had ranges as developed during the test.

Before presenting the table of correlations, a brief explanation of the statistic follows. Correlation measures the degree to which two variables co-vary (increase and decrease) together over their ranges as compared to (actually divided by) the amount of variability within each of them. A correlation only exists between 1.0, a perfect positive relationship and -1.0, a perfect inverse relationship. The strength of a relationship becomes stronger as the correlation approaches either 1.0 or -1.0. A common test of the relevance of a correlation is to determine whether it could have occurred by chance or if it is likely significant from zero. For this sample size, any correlation which equals or exceeds $r=0.208$ should be considered significant from zero. Table 4 describes the computed correlations.

## TABLE 4. CORRELATIONS OF KEY VARIABLES

| | Phase | Position | Yearsatc | FPL/DEV | Stopbar | Traffvol | Workload | Busy | IFRtraff |
|---|---|---|---|---|---|---|---|---|---|
| Phase | | .08 | .09 | -.06 | -.38 | -.07 | -.09 | -.09 | .01 |
| Position | | | .05 | -.11 | -.31 | -.41 | -.32 | -.38 | -.40 |
| Yearsatc | | | | -.41 | -.10 | -.03 | -.09 | -.15 | -.22 |
| FPL/DEV | | | | | .14 | 00 | -.14 | .05 | .24 |
| Stopbar | | | | | | .10 | .16 | .16 | .27 |
| Traffvol | | | | | | | .77 | .79 | .33 |
| Workload | | | | | | | | .83 | .21 |
| Busy | | | | | | | | | .34 |
| IFRtraff | | | | | | | | | |

An examination of table 4 indicates that there were some significant correlations. As with any statistic, interpretation must be made in terms of what was measured and not based on the cpmputed statistic alone. The correlation of -0.38 between stop bar presence and the phase of the study reflects primarily the fact that there were no stop bars operated in the pre-test or what we are calling phase 1. Since the absence of stop bars was coded as a 2 and their presence was a 1, this explains the inverse relationship. The inverse relationships with the position codes and responses to the questionnaire implies that the controllers saw their environment based on the position they were occupying at the time they completed their questionnaires. No one appears to have been overwhelmed in the local assistant position or the stop bar position. This is consistent with what the controllers told us in terms of the difficulty in concentrating when they were trying to work the dedicated stop bar position.

The correlation of -0.41 between controller status and years in air traffic control was not surprising. The longer the controller has been around, the more likely it is that he/she has reached FPL status. Since the FPLs were arbitrarily coded as 1's and the developmentals as 2's, this explains the negative correlation. The correlation of -0.22 between IFRtraff and Yearsatc and that of 0.24 between FPL/DEV and IFRtraff both imply that the developmentals were working during the busier periods. However, despite their significance from zero, these represent rather weak relationships. While the same caution is also valid concerning the r=0.27 correlation between the presence or absence of stop bars and IFR traffic, the result is consistent with the conclusion that IFR traffic decreased as the test progressed from the baseline through the implementation of the stop bars. This aspect of the air traffic control system may well have had a confounding impact on the overall test. One wonders what would have happened during the final phases of the test if traffic had stayed level or actually increased.

The bottom right corner of the correlation matrix is probably the most relevant portion of the entire table. Intercorrelations of the three scales in the questionnaire were all relatively high, ranging from 0.77 to 0.83. This indicates that the controllers were not discriminating very well across their estimates of traffic volume, busyness, and workload. It also appears that controllers' subjective perceptions of the traffic volume correlate better with

IFR traffic than do their individual estimates of workload. Further, it is their perceptions of the traffic volume that appear to be driving their workload estimates rather than the actual IFR traffic itself. The reader will note that at least for the phases covered by the longitudinal study, there was no significant relationship between workload estimates and the presence or absence of the stop bars.

The remainder of the analyses on the questionnaire data will involve some graphical representations and the use of the chi-square statistic. A brief explanation of this statistic follows.

Given two variables (for example, the position occupied by a responding controller and the responses made to a 10 category rating scale), we need to know if ratings are dependent or independent of the position occupied. If there were a hundred participants and 10 categories, then one would expect an even distribution of ratings across the 10 categories unless something besides chance was driving the ratings. Chi-square measures the relationship of the observed frequencies to those expected by chance and provides a probability that the computed chi-square occurred by chance. A significant chi-square indicates that the null hypothesis of independence is rejected and implies that the variables in question are dependent on each other.

Figure 8 describes the mean ratings by controllers on the workload and traffic volume by phase of the test in which they participated. The reader will recall that these variables are well correlated with each other as well as they were with the busyness scale. Not surprisingly, the chi-square analysis on all three variables across the phases of the experiment was negative. For workload against phase, the result was chi = 27.48 ($P > 0.05$). The traffic volume scale produced a chi = 21.26 ($P > 0.05$), and the busyness scale provided a chi = 36.49 ($P > 0.05$). The probability estimates in parentheses indicate that there were more than 5 chances in 100 that the statistic could have occurred by chance, and by standard conventions this means that it is not significant.

Figure 9 shows workload ratings by both position worked and phase of the test. It is apparent that there could be differences in workload based on the positions worked. Chi-square analysis of this information was initially accomplished on all the data without considering the phase of the experiment. The result was a chi = 89.10 ($P < 0.01$). This was highly significant and supports the correlation data that position had an influence on perceived workload. It was decided to break this analysis out by phase and compute statistics for each phase. The results were as follows: pretest chi = 65.73 ($P < 0.01$), phase 1 chi = 73.65 ($P < 0.01$), and phase 2 chi = 43.72 ($P < 0.05$). While the analysis indicated a relationship between position and workload ratings in all three measured phases, the relationship between workload and position in phase 2 was not as strong as it had been in the other phases. Phase 3 was the first phase in which the stop bars were in operation, but there was no dedicated operator unless the local controller called for help. It is unfortunate that the data stopped coming at the end of this phase, and we can only speculate what might have happened if we had questionnaire data in the last phase of the test when there was no spare controller available to support the stop bar operation.

Figure 10 describes all the controller ratings by test phase and position worked. Added to this is the plot of the actual recorded IFR traffic. The impact of the position worked is apparent across all phases of the test. Further, while the

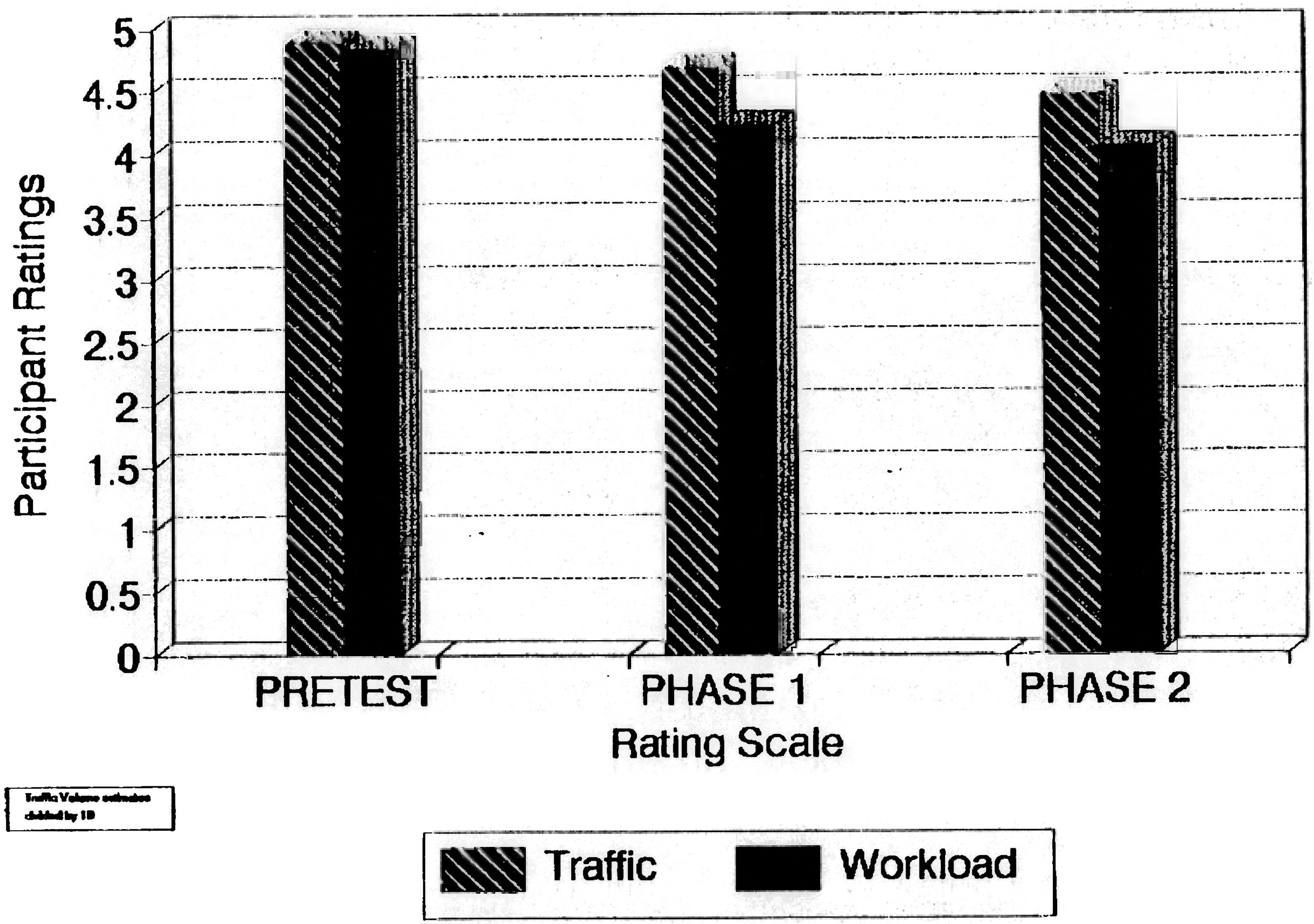
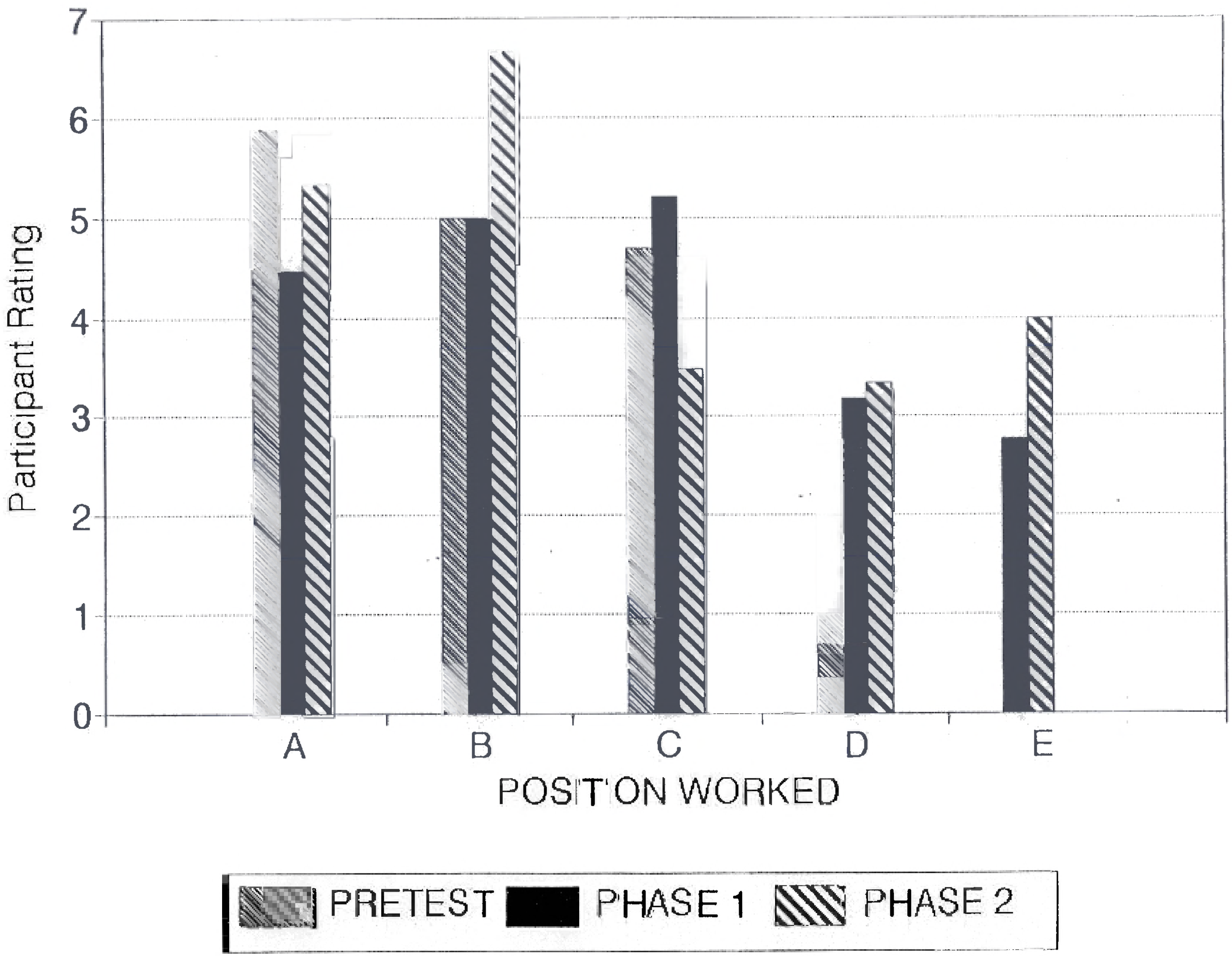



FIGURE 8. GRAPHICAL REPRESENTATION OF CONTROLLER WORKLOAD AND TRAFFIC VOLUME ESTIMATES




GURE GRA 'AL RE RE NT ON TROL WORKLOAD RA NG

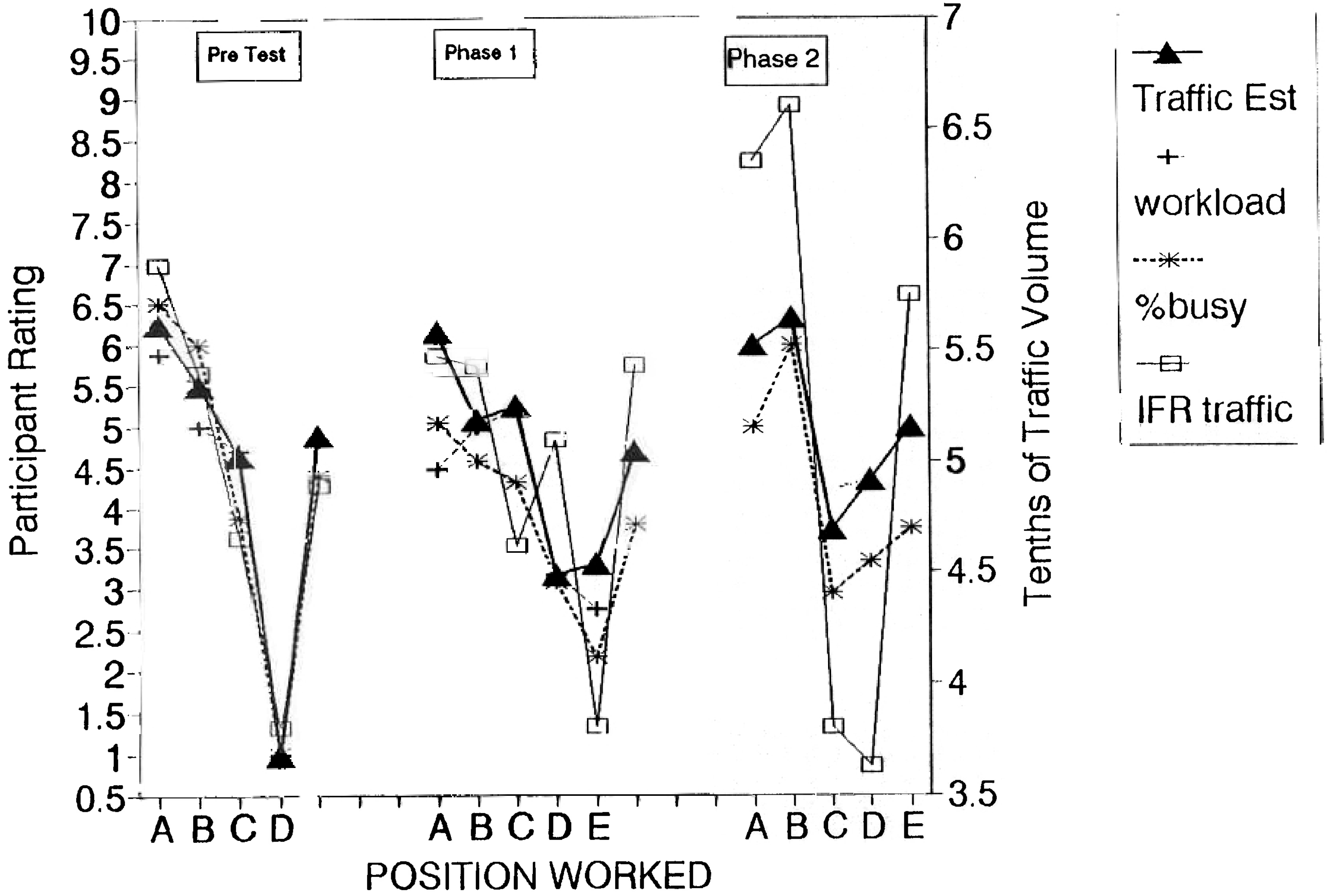



FIGURE 10. GRAPHICAL REPRESENTATION OF RATINGS AND ACTUAL TRAFFFIC

IFR traffic volume and workload are related as indicated in the table of correlations presented earlier, chi-square analysis indicated that this only held across all the data in the test and broke down within the phases. The chi-square for the whole test was chi = 87.81 ($P < 0.05$). However, for the three respective phases none of the chi-squares were significant. Again we come back to the subjective impressions of the controllers. When chi-square was computed on workload and traffic volume estimates (both questionnaire variables) it was not surprising that given their previously reported high correlation, they would not be independent. The resulting chi-square was very large, chi = 396.8 ($P < 0.001$).

Several conclusions are supported by the results of the numerical portion of the questionnaire. There was no quantitative evidence that controllers were overburdened by the system and the stop bars. A number of factors were driving workload besides the presence or absence of the stop bars. These included the position worked and, to a very large extent, the perceptions of the controllers concerning the amount of traffic they were required to handle. However, it would not be reasonable to conclude from this data that the stop bars added no workload. As will be seen in the comments the controllers made to the questionnaire and subsequently to the face-to-face interview (which covered the last phase of the test), controllers by and large were not comfortable with the stop bar system as implemented. That the numerical data did not reflect this may have been a function of either the way the questions were worded or the traditional approach by controllers and pilots alike to underplay and understate an issue that concerns them.

Appendix D lists selected controller responses to the final question of the controller input questionnaire which relates to the stop bar program. The reader may wish to compare these comments, which were made immediately after a control shift, with those made later during the interview portion of the study. There appears to be considerable consistency. Further, there are far fewer comments than response forms completed because the controllers frequently left this question blank.

CONTROLLER RESPONSES - INTERVIEW PROGRAM.

The results of any interview process are based on the subjective impressions of the interviewees. When there is a measure of consistency among the respondents, it adds to the confidence that their perceptions have validity. As will be seen in the results below, there was remarkable consistency in the interview responses from JFK tower controllers.

What follows are summaries of what the controllers and supervisors told the interviewer at JFK tower. Every effort was made to capture the consensus of controller opinion as objectively as possible.

Question 3: Please describe what it is like to work local control at JFK?

Controllers agreed that the local control position is a very active and dynamic focal point in which communications and information transfer are very important. While the workload varies depending on the time of day and the weather, the position requires attention and situation awareness. One-third of the respondents specifically cited the importance of organization and timing in order to maintain the flow of traffic.

Question 5 and 5a: Explain your concept of how the team in the tower cab works together. Who talks to whom and when?

The purpose of this question was to look at the communication patterns in the tower cab with special emphasis on the local controller. Responses indicated a very complex pattern of verbal communication coupled with occasional non-verbal cuing (observed by the author, not cited by respondents). At one time or another, literally everyone in the cab must communicate with everyone else. However, the local controller talks primarily to ground control, the terminal control area (TCA) controller, and to the cab coordinator/assistant local controller. The terminology for this last position seemed to vary with the respondent.

Question 5b: Where do you obtain your critical information besides strips and looking out the window?

The purpose of this question was to identify sources of information that could compete for attention resources besides the stop bar system. Responses confirmed that when working local control, the principle source of information was the D Brite radar display mounted on the ceiling that required the operator to look up, while the stop bar panel required the operator to look and reach down. Other sources of information were airport surface detection equipment (ASDE), other controllers, pilot reports (PIREPS), instruments, and the status information board. The majority of information sources for the local controller are visual in nature.

Question 6: How does the stop bar program affect how the team works together?

This question was based on the hypothesis that when you introduce any new command and control responsibilities to an environment, it can influence what has gone on before and patterns of communication. Of the 22 respondents to the interview, only 2 felt that the program had no impact on team operations. Nine controllers specifically cited increased demands for coordination. One controller noted that they had to develop new techniques to cue a dedicated stop bar controller when it was time to push a specific button. This involved adding words to clearances such as telling a pilot that he/she was cleared for a specific crossing despite the fact that the pilot already knew where he/she was. Ordinarily, the specific taxiway that he/she was on would not be cited in the clearance. They had to do this over an intercom override so that the dedicated stop bar controller would hear the clearance. In order to do this, they were shutting out other intercom verbal input during the transmission of the crossing clearance. Three controllers noted that the stop bar system distracted their attention from primary duties. Four respondents felt that the use of stop bars had a negative impact on their timing and rhythm. Two controllers noted that the control panel for the stop bar system had an impact, based on problems they had trying to find the best place to locate it in the cab.

Question 7: How do you personally feel about the stop bar implementation?

Of the 22 controllers responding to the interview, 16 took this opportunity to say something negative about the program either conceptually or concerning the actual implementation. One person said it was worth testing, and one said that he liked it and that it helped particularly with foreign pilots who may not know the airport. One respondent commented that staffing was the principle worry and that there were not enough people to operate the dedicated position when it was part of the test. One controller felt that the idea of stop bars was good, but that the implementation was ineffective. This controller suggested that wig wag lights would have been more effective in alerting pilots than those that were actually employed.

Question 7a: How does it influence your job directly?

The most frequent single response either directly stated or inferred was that the stop bar system diverted the controllers attention from other duties. Seven out of 22 controllers responded in this fashion, including one who said the system was not a problem if working properly. Six controllers commented that they had mechanical problems with the system, or that the 20-second timer was too short. Several people noted that operating the stop bars did involve extra work. However, one indicated that he liked being loaded and enjoyed working the stop bars along with local control.

Question 7b: Does it change the workload in the tower cab?

Out of 22 respondents, 20 (90 percent) indicated that the stop bar system increased their workload in the tower cab. It increased tower to cockpit radio traffic especially when the system was not working well. It requires mental effort to try to anticipate the arrival of an aircraft at a crossing point, and when the lights time-out too soon, it throws the controllers timing and rhythm off. One controller commented that the increase in workload is only a problem when the other demands on his time exceed a light load level. During low visibility, one controller noted his attention was drawn to the stop bars and away from the radar and other information sources.

Question 7c: How does the actual use of the stop bars compare with the idea behind them (the concept)?

Nineteen personnel (86.4 percent) indicated the concept behind the stop bar program was a good idea. Twenty-one (95.4 percent) of the controllers stated that the implementation at JFK was not effective. Three controllers felt that instead of stop bars, more effective signage and lights not under tower control would serve the purpose of alerting pilots to the active runways. One problem cited on the implementation was the location of the stop bars adjacent to the 22L and 4R runways which are not the most frequently used. The respondent suggested that a better test would have been on the 13/31 parallel runways. This would not have solved the issues cited by the other controllers in terms of workload, attention drain, and mechanical problems.

Question 8: Did you see the stop bar program having an influence on the amount of traffic handled at JFK and if so to what degree?

Thirteen controllers (59 percent) felt that the use of the stop bars had an impact on the traffic flow. The primary problems that they identified involved disruptions of their rhythm for departures, particularly when the lights timed-out prematurely before an aircraft arrived at an intersection. Nine respondents (41 percent) saw no impact on the traffic volume. However, two of these controllers commented that traffic during the test period was down anyway due, in part, to the Gulf war and the recession.

Question 9: In your opinion, will the use of stop bars reduce the opportunity for a runway incursion and make the airport safer?

Question 9a: If yes, why and how?

Categorizing responses to this question involved some subjectivity on the part of the interviewer. If the respondent said anything positive it was placed under question 9a and anything negative was categorized under 9b. Some controllers had something to say which was both positive and negative about the stop bars. Eleven respondents out of 22 had nothing positive to say about stop bars that could be put under 9a. One stated that if they could fix the system it wouldn't hurt. Another commented that an improved system with a dedicated operator might improve safety. Nine controllers saw potential from a stop bar system but most commented that it would have to be changed to be of any use.

Question 9b: If no, then why not?

Eighteen (82 percent) of the respondents indicated that there was no improvement in safety. It was apparent, however, that most of these personnel could not look beyond the system that they were currently using and think in terms of an improved, user friendly system. One of the problems they cited in response to this question was the lack of compliance by pilots, who they said had a tendency to ignore the red lights if given a verbal clearance.

Question 9c: If no, then how could the program be improved so that it could work to increase safety?

Controllers recommended basically two major changes to the stop bar system. First they suggested a better cockpit alerting system. This involved changing the lights on the airport surface to improve their visibility and attention grabbing qualities. The other change concerned the controller interface and communication links between the tower cab and the lights. They want them to be more user friendly and more reliable.

Question 10: Is there anything else that you would like to say at this time concerning the stop bar program or is there anything that I have failed to ask you that you believe is important?

Every controller who participated in the interviews had something to say in response to this question. Appendix E details the interviewer's transcription of their responses. It is not a word for word copy of what they said, but rather the essence of their comments from the interview notes. Basically, controllers took this opportunity to reiterate their concerns about the stop bar interface, the so called mimic panel, the timing considerations which led to breaches in their flow, pilot compliance, and the workload considerations involved in operating the stop bars.

## FINDINGS

1. The majority of controllers and supervisors felt that, conceptually, stop bars were a good idea.

2. Almost everyone concluded that the current implementation did not demonstrate the concept to its full potential. They were unable to look past the implementation to subjectively predict safety enhancements by an improved system.

3. Almost everyone indicated that the system as tested was not workable especially when combined with the local control position at moderate to high traffic load (one exception).

4. Almost everyone exhibited a lack of trust in the reliability of the system (one exception).

5. There was a fairly high probability that pilots receiving a verbal clearance would ignore red stop bar lights. This may be due in part to the JFK stop bar system not conforming to, and being less conspicuous than, the ICAO stop bar design.

6. The automated 20-second time cancel function was frequently cited as a source of complication and frustration. On several occasions, the stop bar lights reverted back to red before the cleared aircraft crossed the stop bar. This often led to additional workload because controllers had to reinitiate the sequence to extinguish the red stop bar lights.

7. The stop bar system frequently required multiple and repeated operations by the controller to complete a single transaction.

8. Repeated operations to complete a single transaction were emotionally frustrating and distracting from the controllers primary scanning and decision-making functions.

9. The person-machine interface was neither user friendly nor efficient.

10. The size of the control panel and its overall design were unwieldy and not system engineered.

11. Locating the panel in the tower was an ongoing problem especially when local control functions were split.

12. The presence of the stop bar control system in the tower cab increased coordination requirements and had an impact on communication. This was particularly notable during periods of a dedicated stop bar position in which all communications had to be via intercom override so that the stop bar controller would hear what was going on. Controllers found themselves developing an enhanced phraseology which increased the number of words spoken. For example,

when clearing an aircraft for runway crossing they would specify the intersection despite the fact that the pilot knew what intersection he/she was on. This was done to cue the stop bar controller.

13. Questions concerning and related to stop bars added to communications load on occasion. This included a recent flurry of queries from pilots concerning amber hold bar lights on intersections that had no stop bars.

14. Controllers were very concerned about stop bar system outages and, specifically, the impact they would have on pilot attitude and attention to detail.

15. There was a very high probability that ground vehicles would cross against a red light. Some controllers reported testing this theory and indicated that every ground vehicle given a verbal clearance crossed against a red light. They also tested this concept with pilots and only about half questioned the red lights.

16. One controller reported that on one day, stop bars on an intersection were stuck on red. Two-hundred departures were verbally cleared and only one pilot questioned the lights.

17. Pilot education is an important issue for a workable stop bar system. However, this requires a consistent airport wide system.

18. Controllers conscientiously attempted to make the system work and did their best to work with what they had available.

19. The majority of controllers felt that the system had an impact on their timing and rhythm when they were busy and/or in IFR conditions.

20. While there were differences of opinion on the impact of stop bar test on capacity, controllers cited the loss of departure windows or slots because the system timed-out on aircraft that did not move fast enough through an intersection. The light reset to red and the pilot stopped and questioned. This also added to frequency congestion.

21. While three supervisors shared many of the same concerns as rank and file controllers, all those interviewed cited one additional issue not cited by any working controllers. The issue was staffing and ensuring that they find enough personnel so that they could provide stop bar support when the local controller was otherwise loaded.

22. In terms of workload, the majority of controllers saw an increase as a result of the stop bars. While at low-to-moderate taskload, this was not a major problem; it concerned them when they were very busy due to traffic demands and/or weather.

23. Workload was also an issue for the dedicated stop bar controller. A number of respondents noted that the task could be a case of underload in which maintaining attention was a problem. Results of earlier surveys indicated that this was not a major problem.

24. There was one full performance level controller who liked the concept of the stop bars and the implementation. He indicated that he believed that it was a matter of adapting to change and learning the system.

25. There were differences of opinion concerning the potential for a stop bar system to improve safety. While some personnel accepted the possibility that the stop bars could enhance safety, 82 percent did not feel that was the case with the current system.

## CONCLUSIONS

Based on the results and findings of this evaluation effort, it is concluded that:

1. The John F. Kennedy International Airport (JFK) stop bar system, based on airline pilot opinion, is somewhat effective in preventing inadvertent runway incursions.

2. The JFK stop bar system, also based on airline pilot opinion, is not as effective as stop bar systems operating at European airports.

3. Although the majority of the controllers felt that conceptually stop bars are a good idea, almost all of them agreed that the JFK stop bar system was not acceptable, especially when combined with the local control position at moderate to high traffic load.

## RECOMMENDATIONS

1. Re-engineer the stop bar system using a systems perspective.

2. Consider all hardware, software, and person-machine interfaces in the re-engineered system.

3. Include human factors and controller personnel in the design process.

4. Develop a controller interface which is flexible, position tailorable, user friendly, and responsive to input.

5. Consider, but not be limited to, the following interface suggestions.

    a. Think beyond mechanical switching technology.
    b. Consider a touch panel interface with both color and shape coding of switches. For example:

        (1) Provide light status on the field by green and red coding of the switches.
        (2) Provide controller feedback that a switch has been thrown by a shape change from round to square.
        (3) Provide feedback that lights have actually changed by a color change from red to green or green to red.

(4) Engineer the system such that the delay from button press to actual light change is minimal.

6. Design the system and communication links between the tower and the field lights such that the delay between control input and light change along with feedback to the controller shall be minimal.

7. Include within the design an automated reset to red subsystem that is not time-based and does not require controller monitoring or physical action. A sensor at the intersection could automatically record the passing of the aircraft and provide a reset. Include the controller option of the multiple aircraft crossings before light reset.

8. Include within the design of the system a program of controller training/-familiarization and a specific program for pilot education.

9. Include within the design sufficient redundancy such that reliability will equal or exceed that of current surface alerting and marking systems.

10. If the stop bars are to be used in conjunction with hold bars at the same airport, ensure that the stop bar lights are discriminably different in hue from any hold bars in use. This can be accomplished by further separating them in the color spectrum and by encoding the stop bars with additional elements such as flashing and intensity.

11. As part of the overall system's design, consider positioning of controller input/output device or devices within the physical structure of the tower cab.

12. As part of the overall system design, consider controller task structure and roles such that responsibilities for stop bar operation are clearly delineated and additional coordination requirements as a result of the stop bars themselves are minimized.

13. Develop the operating procedures, rules, and regulations as an integrated portion of the overall system. The complete package should come with all appropriate documentation.

14. Install red stop bar lights completely across the taxiway at 3-meter intervals, as required by the International Civil Aviation Organization (ICAO).

## APPENDIX A

## DOT/FAA Technical Center
## JFK Stop Bar Evaluation
CONTROLLER INPUT QUESTIONNAIRE

Instructions: The FAA is conducting a study to determine the impact of the new stop bar system on the complexity and workload associated with your job. The study will involve collecting data both with and without the stop bars in use. Please respond to the questions below as honestly and accurately as you can based on your experiences during the period you have just worked as either a local or stop bar controller. All the data is collected anonymously and your privacy will be protected.

Your Background: Participant Code. Choose any 4 letter/nbr combination-use consistently

Years in ATC_____ Years at JFK______

FPL(1) or Developmental(2)? Hours Just worked:From__ To
Circle one Time on 24 hour Clock

Position Just Worked(Circle one)
A Local(DEP) B)Local(ARR) C)Local(COMB) D) Assist Local E)Stop Bars

Are the stop bars in use today? Yes No

In every facility the traffic volume varies over time. Below please rate the volume of traffic you were working during the last period of control. Circle the one number which best describes the traffic volume.

**Traffic Volume**

Low 1 2 3 4 5 6 7 8 9 10 Very High

You have just experienced a certain amount of workload which will vary from day to day and form one person to the next. Below, please circle the one number which best describes how hard you had to work during the time you just completed. The rating scale runs from 1(very easy-all tasks easily completed) to 10(very hard-some tasks difficult to complete).

**Workload**

Easy 1 2 3 4 5 6 7 8 9 10 Very Hard

In most jobs the work ebbs and flows. Below please estimate the percentage of time during the last period on position that you were really busy. Circle the one number which best describes the % of time you were busy.

**Busyness**

% 10 20 30 40 50 60 70 80 90 100 %

Is there anything else that happened during your last time on position that might help us understand the workload and performance that took place? Use the reverse side for more space.

Refer any questions to Dr. Earl Stein FAA Technical Center FTS 484-6389.

APPENDIX B

STOP BAR SYSTEM MALFUNCTIONS

During the period of the maintenance contract, the following system malfunctions were addressed and remedied:

| DATE | ACTION TAKEN |
|---|---|
| 3-27-91 | Replaced K-1 contactor in power/converter unit. |
| 3-28-91 | Replaced K-1 contactor in power/converter unit. |
| 4-29-91 | Replaced one pushbutton switch on mimic panel. |
| 5-31-91 | Replaced K-1 contactor in power/converter unit. |
| 6-03-91 | Repaired loose connector on mimic panel. |
| 6-06-91 | Cleaned contacts of K-1 contactor and replaced PC board in power/converter unit. |
| 8-14-91 | Cleaned contacts of K-1 contactor in power/converter unit |
| 9-05-91 | Replaced time-out timer of radio remote terminal unit. |
| 9-08-91 | Repaired time-out timer circuit of radio remote terminal unit. |
| 10-19-91 | Repaired loose plug in radio remote control base station unit. |
| 11-05-91 | Replaced entire power/converter unit. |
| 12-16-91 | Replaced control PC boards in two power/converter units. |
| 1-15-92 | Replaced 5 VDC power supply in mimic panel |
| 1-24-92 | Cleaned contacts of K-1 contactor in power/converter unit |

## APPENDIX C

## SUMMARY OF PILOT COMMENTS

Pilot comments as recorded by the pilots on the evaluation questionnaire forms are shown below. The excerpts, while not necessarily direct quotes of individual pilots, reflect the general nature of the comments.

1. The JFK stop bar system should be more distinctive. The lights would be more effective if they were installed completely across the taxiway. Three inset lights are not enough. (11 pilots)

2. Stop bar systems in Europe appear to be brighter and more eye-catching than the JFK stop bar system. (4 pilots)

3. The JFK stop bar system is a good visual aid. (4 pilots)

4. The JFK stop bar system is inadequate and should be designed to meet ICAO standards in order to be commensurate with stop bar systems in foreign countries. (3 pilots)

5. The JFK stop bar lights revert back to red too soon - usually before the aircraft crosses the stop bar. (3 pilots)

6. The stop bar system at JFK is a step in the right direction. (3 pilots)

7. Stop bar systems should be installed at other airports. (3 pilots)

8. The red stop bar lights are not red enough to distinguish them from the amber hold lights. (2 pilots)

9. The JFK stop bar system can be confusing. (1 pilot)

## APPENDIX D - SELECTED CONTROLLER RESPONSES

Final question of the controller input questionnaire: Is there anything else that happened during your last time on position that might help us understand the workload and performance that took place?

<u>DATE</u> <u>RESPONSE:</u>

03-12-91: Aircraft accident, runways 14/32, 13L/31R, 4L/22R, 4R/22L, all closed Departure and landing runway 31L, with numerous departures and arrivals.

03-12-91: Aircraft accident, unusual runway configuration.

03-26-91: Stop bar 14 was the only one in use, and it was not working properly I was informed that the relay for stop bar 14 had to be replaced.

03-26-91: The 20 seconds that the stop bars stay green is not enough when telling the aircraft to "taxi into position and hold." Numerous times I had to "time cancel" to keep the green lights lit longer.

03-27-91: Stop bar 9 is the only one in use due to protection of critical areas. Stop bar 9 was intermittent and had to be reset several times.

03-27-91: Unable to see runways due to fog. Airport surface detection equipment (ASDE) presentation is poor.

03-28-91: You can never be sure if the stop bar is going to work; when you have to take the time out to watch the stop bar panel and see what it does, it takes away from your other functions.

03-29-91: I noticed many times when the local controller gave a command that required the use of the stop bar, the local controller would glance down to make sure the proper command was followed through. A tone on the monitor position made it more difficult and more distracting.

04-02-91: Stop bar 8 (H) - relays continually sticking.

04-03-91: Landing 22L - Departing 22R aircraft rolling out 22L, turned off at "J", was instructed to taxi via "J" and hold short of 22R. Aircraft missed "J" taxiway, proceeded via "Z". Appeared to cross the 31L stop bar, and then appeared to stop short of 31L on its own. Stop bar panel showed red for stop bar 15, the 31L stop bar on "Z" side, intensity set at step 4. Stop bar appeared <u>ineffective</u> in avoiding a potential runway incursion on runway 31L.

04-05-91: Stop bar was combined with departure local. Early in the session, the light changed back to red before aircraft was able to taxi into position. It appeared that there was 20 seconds time between the change over to the red light was shorter then usual. Not only did it increase my work load at that particular time, but I felt distracted to constantly check the light and aircraft's position instead of checking runway and radar.

04-05-91: Terminal control area (TCA) combined with local control, TCA traffic distraction from local control functions.

04-09-91: Time-cancel on stop bars is incredibly frustrating. It's either too long or inadequate. Controller should be able to immediately affect color of lights.

04-12-91: Local combined with TCA increased work load.

04-14-91: I continue to find the time delay inadequate, and I feel that an adjustment to the time will not relieve the problem. Either the time is inadequate for the required operation and the stop bar must be time-cancelled manually, or the time is too great and a manual cancel must be activated to prevent aircraft (that the lights are not intended for) from using the clearance. I feel uncomfortable with the mimic panel and the way it presently is operated. The slow, unpredictable response of the panel is, at the very least, distracting and, at the most, could be hazardous. Reserving any opinion as to the inherent existence of the stop bars at this time, I wish to state that I would feel better about their operation if I were more in control (i.e., toggle switches, where I move a switch, it stays in position, and the light is definitely lit appropriately. When the aircraft is clear the switch comes down, the light reverts to red -- no question, no undesired lights at other intersections changing, and less attention to the mimic panel's operation and more to the stop bars).

04-15-91: Stop bar 2, when pressed, flashes green on panel, but aircraft reported it steady green. Numerous times stop bars 1, 5, and 7 were selected and time-cancelled so that they would remain green but they changed after 20 seconds to red.

04-15-91: Stop bar 2 does not set and reset properly on the mimic panel. Lights change properly on the field, but flash on the panel. Test button must be used to get a solid light on the panel.

04-15-91: Still finding myself checking the stop bar to make sure the buttons are being depressed.

04-16-91: Having no visual references it is sometimes hard to judge just when an aircraft has crossed over or is holding short of 22R at the approach end. Traffic going into position for 22R sometimes takes longer than 20 seconds, and with no real visual reference, you cannot really tell if aircraft has passed the stop bar.

04-16-91: Stop bar 2 flashes green when selected, and when it goes back to red, flashes red

04-18-91: Many times when you time-cancel a green light, the system alarms

04-18-91: I worked departure local control from 1900 to 2000 LCL (2300-0000Z), which is <u>after</u> the evaluation period. However, during my time working departure local control, I would estimate that two-thirds of the aircraft put into position at the approach end of runway 31L needed more than 20 seconds. In other words, the lights automatically turned back to red prior to the aircraft entering the runway. It's obvious 20 seconds is not a long enough interval for the lights to stay green. Also, a couple of other times during this time on position, the lights would alarm for unknown reasons.

04-19-91: Stop bar's time of 20 seconds is not enough

04-22-91: Time for the approach end lights sometimes is too short, especially when a small aircraft goes into position after a heavy jet departs.

04-23-91: Aircraft taking the runway for departure, sometimes do not taxi fast enough to beat the changing of the lights.

04-30-91: With no visual reference and a poor ASDE presentation, you can't tell if the aircraft have already passed the stop bars or not. The 20-second time had elapsed, and lights went back to red. Aircraft held short, and advised the tower that they were holding short because the lights were red.

05-28-91: Closed taxiways increased complexity of sequence, causing delays. The 20-second stop bar time isn't long enough.

06-23-91: Stop bars at "F" and "G" out of service. "G" taxiway take off closed.

07-14-91: Stop bars 2, 6, and 7, out of service.

07-28-91: Stop bars "G" west and east, out of service; stop bars "F" west out of service.

10-29-91: Also, combined with TCA, too many distractions. AAL1 went through red lights, after I forgot to turn them on. He had received a verbal clearance.

10-29-91: (1) Stop Bar 4 (eastside "F") in constant alarm.
(2) More than 20 seconds is needed before lights turn back to red.

11-08-91: If local control is very busy and working stop bars at same time, he doesn't have time to correct any problem that occurs on the mimic panel. He must concentrate on traffic, and if lights don't change, traffic will be delayed.

## APPENDIX E -INTERVIEWER'S TRANSCRIPTION OF CONTROLLERS' RESPONSES TO QUESTION 10

The numbers 1 to 22 were arbitrarily assigned to the respondents so that, if necessary, comments on different questions could be linked. These numbers are in no way associated with the identities of the respondents.

Question 10: Is there anything else that you would like to say at this time concerning the stop bar program or is there anything that I have failed to ask you that you believe is important?

Number 1. He may have to push the button many times before the light times out. When he clears several aircraft at one intersection he must watch the panel and push buttons multiple times. When pilots are paying attention to the lights, it is a good thing. Pilots are now questioning hold bars. The respondent had an incident in which a pilot crossed a red stop bar and was not cleared to cross an active runway. An aircraft taking off called the controller's attention to the situation. He had noticed but could not do anything at that point. The departing aircraft had rotated prior to the intersection.

Number 2. He receives questions from pilots on lights where there are no stop bars. Pilots will go with the verbal clearance regardless of lights the bulk of the time. The stop bars can throw his sequencing and timing off. With severe weather you need a dedicated stop bar controller. Even then, there is a chance for error because the stop bar controller may not have the picture.

Number 3. About 80 percent of the time (the respondent's estimate), the lights time out to red too soon, and he has to press the button again. At times, the pilot will go through the red lights anyway. Extra transmissions complicate his work. The stop bars throw off the pattern of his control. Even with a dedicated stop bar controller, a lack of coordination could increase the chances of error. The respondent feels the system operation should be automated. Dedicated controllers, he has observed, looked bored or distracted.

Number 4. The system may not accept his input initially. This requires additional button presses and radio transmissions. The lights sometimes cancel themselves. Coordination requirements are extensive even in good weather. The panel itself was poorly designed. They need a visual reference on what is happening on the field with the lights. The mimic panel is awkward to position in the cab. When the lights time out, sometimes pilots will stop and wait while not contacting the tower. The system was not perfected prior to installation.

Number 5. At times, when they are underload because of weather and traffic, it can be tough to keep up with the lights which time out, and they have to push the green light button several times. The system may not be set up to operate as quickly as they use it. If the stop bar lights are green and the controller has given no clearance, there is some chance that the pilot will proceed based on the lights alone. Using a dedicated stop bar controller is a waste of resources. Combining the job with local control increases work load. Anything extra which takes concentration increases the chance of error.

Number 6. He was never comfortable with the feedback lights on the control panel. He would like rapid feedback (immediate) on the status of the lights on the airport surface. He did, however, appreciate the stop bar overtime. The controllers set stop bars as a low priority. A good stop bar system will require good design and effective user education. The stop bars should be implemented for continuous use or not used at all. Aviation is very strongly controlled by habit.

Number 7. At peak periods they were not using the runway that had the stop bars (4L/22R), so the stop bars did not receive a good test. Pilots only questioned the lights when going into position. Crossing runways, pilots were not concerned with the red lights.

Number 8. One day, 200 departures were made across stuck red stop bars. Only one pilot questioned the issue. The deterrent effect of the red lights is not there. Pilots could not discriminate hold from stop bars. Part of the problem is that the stop bars are on only one runway. Pilots are treating the verbal clearance as the final authority. A hardwire rather than a radio based control system is required. Time delays are unacceptable. The dedicated stop bar position was not good because there was not enough to the job to allow the operator to maintain concentration.

Number 9. Working split locals, they have to orient the mimic panel so that each has access. When you press the stop bar buttons, the lights do not always change. Also, if he/she gives a crossing instruction and pushes a button after receiving an approval from the other controller, the green lights can time out and the pilot stops and questions. The respondent does not want to time cancel because he/she may forget to reset to red. The stop bar lights in ground are easily obscured. The lights at the edge of the taxiway should be elevated. Pilots who depend on seeing the lights may not respond to obscured lights. The radio control of stop bars is a problem. Some pilots have stopped at amber lights and questioned when the lights would turn green. This leads to frequency congestion.

Number 10. If the stop bar does not turn green immediately and the pilot called, it slows your rhythm. It takes the attention of the controller to the panel itself. The lights time out too soon and this also slows things down. When working dedicated stop bars, it is difficult to anticipate the moves of the local controller. An aircraft crosses red lights, the controller clears an aircraft, and the pilot waits for amber hold bars to turn green. He may not call the tower, but just wait. This backs up traffic. The respondent has observed controllers locking stop bars on green to facilitate multiple crossings, getting busy and forgetting to reset the lights. There is a need for better runway identification, but more emphasis should be put on correctly identifying the runways with a more efficient operator switching system. Flashing red strobes would be safer. A major problem involves pilots who do not know they are entering a runway. This is a problem with foreign carriers. A dedicated controller is not even an answer, he may be a hindrance as well as a help.

Number 11. Pilots cross red lights. The stop bar system is distracting from primary scanning. Pilots are second guessing the controller's instructions. The aircraft has been cleared and the green light times out. The pilot calls and asks if the clearance is still good. This adds to frequency congestion.

Number 12. The time out on the red lights is ineffective. Currently there is paranoia among pilots about the lights, and they question amber hold bar lights. They confuse them with red lights. The system was thrust on JFK without controller input. If the system was hardwired, it would be more effective. The way the stop bars were tested at JFK was not a fair test. Put in properly, the system could enhance safety.

Number 13. The outbound push is easier than the inbound. The exception is when departing pilots ask a lot of questions, which they may do if the stop bars are not operating properly. They do not trust the reliability of the system; the signals on the mimic panel were very confusing. When lights flashed on the panel, the controller was not certain what was happening on the field. They would say that the signals indicated a certain performance, but there was nothing to support this, short of sending a vehicle out to the intersection. Controllers tested pilots by giving verbal clearances and leaving the lights on red. Only about half the pilots questioned this. They performed the same test with an unspecified number of ground vehicles and none questioned the red lights. They have had pilots question red lights at an intersection where there are no lights except taxi lights, not even hold bar lights. There were no stop bars at some intersections due to construction, so controllers avoided using the intersection at night and in bad weather. This reduced the controller's options.

Number 14. When there was a dedicated stop bar controller, it was very difficult to maintain concentration. If he missed something, he had to ask local control which broke that controller's concentration. The Port Authority should improve hold bar markings, and taxiway signage in place of hold bars. Pilots cross red lights out of habit; they spool up to adhere to a verbal clearance and do not want to panic stop when the green light times out. If you lock the light on green, there is a risk that you will forget about it, and a pilot (foreign) may go with the green light. The respondent is looking forward to the termination of the program. JFK must be a difficult airport for this test because of foreign carriers who require more communications. Airport signage at JFK needs improvement; it increases controller workload because pilots need more help.

Number 15. There is a trade-off with the stop bars. There is increased workload, and pilots will ignore red lights. The respondent feels that he could live without the stop bars. If separation is adequately maintained, then stop bars are unnecessary. He is unsure that red lights would stop an incursion, even if they were working adequately. There are currently no adequate reference points visible from the tower, concerning the relationship of the aircraft to the hold bar/stop bar line. The respondent is concerned about liability, even with a dedicated stop bar controller. Pilots are questioning amber lights on intersections that have no stop bars; this slows the traffic flow.

Number 16. He sees the efficiency of stop bars as no more than 70 percent. This refers to how well it worked to actually stop aircraft. With a dedicated controller, he must coordinate with local and ground controller. He would like to see the stop bar equipment improved. The panel and buttons are poor, and the wiring is faulty. Stop bars might work better at a smaller airport where the complexity is lower.

Number 17. The pilots cross the red lights even at maximum intensity. ALPA posted a warning, and more pilots questioned the red lights when controllers failed to push the button. The stop bars can throw off controller timing. Pilots may even question amber lights on intersections with no stop bars. This is a distraction from higher priority duties. Controllers concentration is distracted by whenever the green lights will time out prematurely. When you push a button, there is a time delay which is disconcerting, and there are mechanical flaws in the system. If the purpose is to increase safety, find ways to reduce frequency congestion and reduce heads-down time. The current stop bars do exactly the opposite.

Number 18. The lights can time out too soon. Pilots are noticing them more now than at the beginning. The 20-second delay was a problem. It required multiple inputs which adds a lot of stress. If you forget to turn the lights, the same problem occurs. One pilot referred to the lights as itty-bitty things. The taxiway intersection hold lines do not look that different from the hold bar lines. Better marking would help. Pilots are beginning to question amber hold bars. With stop bars when you set (lock) bars on green you may forget to reset them to red. He has not seen aircraft cross at a green light against a verbal hold-short instruction. Location and sharing the control panel was a problem. If all they had were departures, they would lock the light on green so they wouldn't have to attend to it. When working a dedicated stop bar position, it was difficult to stay on top of it. You start day dreaming. This has led to response delays and conflicts between the local and stop bar positions.

Number 19. Visual cuing of pilots that they have reached a runway could reinforce the verbal command. Respondent feels that using the stop bars is a matter of learning the system and getting used to operating it.

Number 20. The button design is poor. You may push it, and it does not take. The stop bar system is labor intensive. The test was not adequately funded to test it fairly. During split locals, it was unclear how/where to locate and operate the system. The system was not well thought out from its inception. JFK did have some incursions, and a panel studied the problem. Recommendations were made and followed, such as increased use of ASDE. It improved things, but stop bars have not had an impact. Stop bars will not resolve controller errors, if he/she hasn't ensured adequate separation in the first place.

Number 21. If they push the button late, the aircraft will cross on the verbal clearance. The pilots do not notice the red lights. There are times when there is no one to work the stop bars, and the cab coordinator must work it. Stop bars do not seem to make a difference.

Number 22. It is easier for the local controller to operate the stop bars himself, than coordinating with a dedicated stop bar controller. When working the dedicated position, it is very difficult to stay alert. It also is frustrating to listen on the frequency to the local controller, especially if he makes a mistake. Who is responsible? It is unclear. The respondent has seen aircraft cleared through red lights, and the pilots seldom question it. He has also seen an instance where a controller gave a verbal clearance when the lights had changed back to red, and the pilot stopped and questioned it. When you tell pilots to disregard stop lights once, they may ignore them at other subsequent times. If more positions were added to JFK, then the stop bar system might have been better accepted. The stop bar system was down too much, and selected intersections have been down indefinitely. The mechanical reliability is also very important. The mimic panel was not reliable. Would prefer a toggle switch control system. Also, wants instant feedback on system status and would like instant control of lights on the field without delays.