NASA Contractor Report 3199

NASA-CR-3199 19800011509

NASA TLA Workload Analysis Support

Volume 1 - Detailed Task Scenarios for General Aviation and Metering and Spacing Studies

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CONTRACT NAS1-13741
MARCH 1980

NASA

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Volume 1 - Detailed Task Scenarios for General Aviation and Metering and Spacing Studies

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Prepared for
Langley Research Center
under Contract NAS1-13741

National Aeronautics
and Space Administration

Scientific and Technical
Information Office

1980

FOREWORD

This technical report covers work performed under Change Order of NASA contract NAS1-13471, "Timeline Analysis Program." This study effort was initiated to develop detailed task workload scenarios for one general aviation instrument flight studies and five commercial aviation metering and spacing techniques utilizing advanced electronic displays.

Work was performed under the guidance of Amos A. Spady, Jr. as technical monitor. Additional contributions were provided by Max J. Kurbjun in definition of objectives and Kathryn Smith in resolution of computer programming problems.

This contract effort covered the period from September 30, 1977 through September 30, 1978 at the NASA/Langley Research Center, Hampton, Virginia. James L. Sundstrom was the principal investigator and requirements analyst, Arthur F. Anderson was the program analyst, and Wayne D. Smith, program manager, and Donald L. Parks provided direction and assistance in the human factors area.

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1.0 INTRODUCTION AND SUMMARY

The purpose of this report is to summarize the efforts required to develop detail task data for six new timeline analysis (TLA) detailed task scenarios. These detail task scenarios reflect the requirements for general aviation, metering and spacing, and terminal control vehicle (TCV) research studies. This volume will provide an outline of steps required to initiate a detailed task scenario and resulting examples. Volumes 2 and 3 provide detailed report data (CR- 3239 and CR- 3240).

The Timeline Analysis (TLA) program was originally developed to aid the National Aeronautics and Space Administration (NASA) Terminal Control Vehicle (TCV) program studies. The emphasis of the TLA program was to provide detailed task-by-task scenarios that would provide measures of crewmember workload demands for normal and abnormal flight situations.

The present contract was to adapt the TLA data to the following studies:

1. A general aviation single pilot instrument flight research

2. A study on metering and spacing techniques and also the installation of a cockpit display traffic indicator (CDTI) in airline flight decks

3. An extension of the original TCV scenario to show autopilot control operation in the forward flight deck.

Item 1 required a complete buildup of task data representative of the aircraft being simulated in this study. Items 2 and 3 basically required modification and reorganization of the existing TLA data file. The new detail task scenario data developed under the above efforts was submitted against the TLA program for validation purposes, i.e., checking the data order to remove errors that may have occurred during the creation of the scenario data.

The TLA program is general in nature, hence, it lends itself well to many different applications. The current NASA TLA program configuration requires large amounts of work for the analyst to create or substantially modify any scenario. This results from the scenario building technique being one of iteratively filling in the blanks, i.e., first define the major events and then go back and fill in the basic tasks required to fly the airplane. The major problem is to fill in the scenario as completely as possible to reflect a continuous workload situation. It is the "gap filling" requirement for the continuous workload picture that restricts the effectiveness of the TLA program. The NASA TLA program needs to be refined to reduce scenario construction and report generation in order to further increase the program utility and productive analytical work.

1.1 BACKGROUND

The TLA program contract NAS1-13741 under change order 4 specified two tasks. These two tasks were: (1) develop scenarios to be used with the general aviation single pilot instrument flight research (GA-SPIFR) studies, and (2) develop one or more scenarios to be used in the studies pertaining to metering and spacing (M/S).

Additionally, another scenario was tasked to describe the workload associated with the standard forward flight deck functions in TCV operations. This scenario was created to extend the data of the original scenario group in which all forward flight deck operations were manual control while all aft flight deck operations were 4-dimensional (4D) auto-control. It defines the activities required to operate from the forward flight deck of the TCV aircraft while using a standard airline-type autopilot, i.e., inputting pitch and attitude information via the control wheel steering feature.

These scenarios, as with the original TLA scenarios, were developed from descriptions of major flight milestones called key events. The key events are described by procedures (set the flaps, lower landing gear, etc.) which are composed of the individual tasks (unique operations) that need to be performed in order to accomplish the procedure. Each task demand is allocated to two or more of the nine possible crewmember workload channels utilized to accomplish the task. The channels are internal and external vision, left/right hands and feet, audition, verbal, and cognition. Every task is considered to impact the cognitive channel.

The general aviation, M/S, and TCV scenarios reflect nominal workloads based on published checklists and operating procedures for the aircraft involved.

The baseline detailed task scenarios assume all workload tasks to be accomplished correctly and without repetition when indicated.

1.2 SUMMARY OF SCENARIO DETAILS

The following discussion summarizes the elements of the developed scenarios and major observations resulting from their construction and validation. Also, preliminary workload-related information resulting from the validation efforts is presented as a matter of general interest.

1.2.1 GENERAL AVIATION SINGLE PILOT IFR

The general aviation single pilot scenario details the efforts required to depart, climbout, enter a holding pattern, enter an air traffic pattern via radar vectors, and fly a landing approach within a high-density traffic area. All procedures and tasks were developed to depict the workload required to operate a Cessna 172-series aircraft in the Atlanta, Georgia, high-density traffic area by a single pilot. This effort required a complete data file development, i.e., new tasks were defined based on a Cessna 172-type cockpit arrangement and organized into procedures as required by the checklists and operations manual.

The scenario was validated by the TLA program. Initial validation reports appear to indicate an imbalance regarding visual versus cognitive workload, pointing out a need for redefining the weighting procedure used to define the cognitive channel. All other workload channels appear to be rational.

1.2.2 METERING AND SPACING (M/S) SCENARIOS

Four detailed task scenarios were created for this task: two for the Longmont arrival path to Denver and two for the Byers arrival path. Each set consists of one scenario depicting the use of manual (hands-on) flight controls and autothrottles, and one scenario depicting the use of 2D autopilot flight path control also using autothrottles.

These scenarios start with the aircraft already in an en route descent. The Longmont approach is a more classical air traffic pattern utilizing a downwind and base leg to the final approach path, whereas the Byers arrival path is basically a straight-in approach to the Denver airport.

The M/S task scenarios were validated (checked for data errors) by the TLA program. These efforts automatically provided preliminary information regarding the workload profiles.

Overall, a comparison of the manual scenario versus the autopilot scenario does not show a large workload differential. This is due to the fact that the majority of the workload was visually oriented for both scenarios. Basically all that changed was the hands-on workload, i.e., the workload associated with manually flying the airplane.

1.2.3 FORWARD FLIGHT DECK AUTOPILOT SCENARIO

This task scenario was created by modifying the in-flight phases of the original TLA TCV program, i.e., climb, en route cruise, descent, approach, and land. The modification consisted of removing all straight-and-level manual control procedures from the affected phases. These phases then describe the effort required to fly via manual autopilot with pitch and directional changes input through the control wheel steering feature.

The initial TLA validation reports for this effort indicate that, as might be expected, there is a reduction in workload for the motor, cognitive, and weighted average channels. (More detailed analyses of the results were not performed due to contract time constraints.)

2.0 TECHNICAL APPROACH

The most recent TLA task requirements were to develop six new additional detailed task scenarios. One scenario (general aviation) was built from scratch and the remaining five were produced by modifying the existing TCV data file to show the required operations. The following is an outline of the general approach to building a detailed task scenario and the associated TLA data file from the beginning:

1. Define the purpose for developing the scenario

2. Define a route structure, or an area of operations that will present the activity to be studied

3. Write a descriptive scenario of the events that will take place for the length of time the scenario is assumed to be active

4. Outline the complete scenario in terms of events or key milestones, i.e., start takeoff, start turn, level off, descend, intercept final approach course, land, etc

5. Develop procedures, based on the checklists and operations manuals of the aircraft type, which will fully describe the activities required to reach and pass the key milestones

6. Define each procedure, in turn, by the discrete tasks or points that must be looked at, actuated, or switched in order to accomplish the activity, e.g., setting the flaps requires actuating the flap lever, monitoring the flap position indicator, checking the leading edge indicator lights, monitoring airspeed, and all associated communication that accompanies this procedure.

7. Items 4 through 6 are broken into four distinct groupings:

    a. The key events are grouped to describe phases of flight. Flight phases are directed to accomplishing one of the major key milestones. For instance, the takeoff phase includes all procedures and tasks required from takeoff clearance through raising the gear. This phase is followed by climb, enroute cruise, descent, approach, and landing. In the data file, the PHASE description consists of all procedures active during the time period of the phase.

    b. The procedures are broken out separately since they may be used in any phase if they are applicable.

    c. The tasks are also grouped separately in the data file as the most basic unit used to describe workload activity. They are grouped by the subsystems involved by the task.

d. The subsystems breakout is used to develop a measure of workload activity by subsystem. This breakout basically follows the specification for Manufacturer's Technical Data, ATA (Airline Transport Association) Specification Number 100, revision II (also see ref. 1). The differences for TLA are that the subsystems were not defined for secondary and tertiary levels nor was the ATA numbering system used.

The steps above develop the phase, procedure, task, and subsystem data necessary to describe in detail the activities required to perform as described by the written scenario.

However, before the detailed task data can be submitted to the Timeline Analysis Program for validation, it is necessary to define the time required to perform each task and allocate that time to the appropriate operator channels. Operator channels are those physical attributes required for task performance: vision (internal and external), communications (audition and verbal), and motor activity (left/right hand and foot). Also, all tasks are, by definition, said to impact cognition; therefore a small percentage of every task time is allocated to the cognition channel.

Task time definition requires the following steps:

1. All switches, gauges, and controls must be defined in X, Y, and Z coordinates relative to the right eye and right shoulder design points.

2. The computed distances are then applied to the task ordering as described by the procedures. (Note: The same task may be used from several different positions requiring more than one task number for the same task.)

3. Finally, human factors data regarding reach and look times between points are applied to the task distance ordering to define each task time.

4. The task times are then allocated across the operator channels on a percentage basis. If the task is discrete it requires a 100 percent utilization of the operator channel, otherwise the percentage allocation will be less. (An example would be setting a switch which requires it to be identified visually and operated manually. The total task time may require only 20 percent visual activity while requiring 100 percent manual activity and some small percent for thinking about the task.)

The above activities produce the detail task scenario to be validated by the TLA program. It is only after the above activities have been accomplished that workload evaluation and analyses can begin. However, once the data file has been developed, defined, and debugged subsequent workload efforts will generally only require data file modifications.

3.0 ABBREVIATIONS

AFD	Aft Flight Deck
ATC	Air Traffic Control
CDTI	Cockpit Display Traffic Indicator
FFD	Forward Flight Deck
GA-SPIFR	General Aviation Single Pilot IFR
IFR	Instrument Flight Research
MC	Manual Control
M/S	Metering and Spacing
R	Radial
TCV	Terminal Control Vehicle
TLA	Timeline Analysis
VOR	Very High Frequency Omnidirectional Range
2D	Two-Dimensional Navigation

4.0 SCENARIO RESULTS

This section provides a discussion of the three major groups of study scenarios, i.e., general aviation, M/S, and TCV forward flight deck (FFD). Each area will be addressed separately in terms of purpose, description, data development, and outputs.

4.1 GENERAL AVIATION SINGLE PILOT IFR SCENARIO (GA-SPIFR)

4.1.1 PURPOSE

The purpose behind this scenario was to provide a basis to later define and study nominal/off-nominal workloads that might be encountered by a general aviation single pilot in IFR conditions in an ATC high density traffic area. The result of the study was to be a baseline that could be used to develop procedures and/or equipment that might reduce the work-loads associated with single pilot instrument approaches.

4.1.2 DESCRIPTION

A plan view of the general aviation single-pilot instrument flight rules (GA-SPIFR) flight profile is shown in figure 1. As noted on the figure, the operations were assumed to take place at the HARTSFIELD Atlanta International Airport (Atlanta). The flight as shown encompassed: (1) a departure from Atlanta, (2) climb via the runway 8 ILS missed approach path, (3) a holding pattern at the missed approach fix, (4) radar vectors to the final approach course, (5) and, an ILS final approach to landing. The complete scenario from takeoff to landing requires 40 minutes. All task activities presented in this scenario are representative of the Cessna 172-series aircraft. Activity details were derived from the checklists and operating instructions of the aircraft plus activities required by the ATC system.

The detail description is as follows:

> The flight begins with the aircraft in position ready for takeoff. Upon receiving the air traffic control (ATC) takeoff clearance, the pilot applies full power to start the takeoff sequence.
>
> After rotation and liftoff, the pilot raises the flaps, climbs straight ahead, and contacts the ATC departure control. The pilot receives instructions to climb to straight ahead to 1500 ft, then turn left climbing to 3500 ft via the outbound Atlanta VOR (very high frequency omnidirectional range) radial (R) 360 to the TROY intersection and hold NORTH.
>
> The pilot then sets up the proper navigation radio frequencies to intercept both the ATLANTA VOR R-360 and the TROY intersection defined by the Atlanta VOR R-360 and the 254 radial from the NORCROSS VOR. Upon reaching the intersection the pilot enters a holding pattern with the outbound leg heading 360 using right turns.

While in the holding pattern, the pilot receives ATC instructions to depart the holding pattern and follow ATC radar guidance vectors to the final approach course. Upon reaching the final approach course, the pilot flies to touchdown using ILS procedures. The scenario terminates at the completion of landing roll.

A gross timeline from the above scenario were described by phases—takeoff, climb, cruise, holding, descent, final approach, and events—liftoff, flap settings, radio changes, and landing. Inspection of the basic profile, aircraft type, and area of operation will provide selected scenario elements (e.g., takeoff, cross outer marker) which provided time constraint estimates. The time estimates provide a gross timeline which was refined by an iterative process.

The detailed flight profile procedures and tasks were then developed by personnel of the Stability and Control Branch of the Flight Dynamics and Control Division at the NASA/LRC. Preliminary results of this effort have been reported in NASA Technical Memorandum 78748 (ref. 2) co-authored by David A. Hinton and John D. Shaughnessy.

The data file created for the general aviation scenario effort is a permanent datafile in the computer system at NASA and under the control of the Stability and Control Branch personnel. The data file will not be presented in this report.

4.1.3 DATA DEVELOPMENT

The general aviation task time data were developed independent of the TCV data file as the location and sequencing of task elements is substantially different for the general aviation aircraft. However, the analytical procedure and techniques used to develop these data were the same as those used to develop the TCV data.

Basically the data development techniques based on panel arrangements and procedures were:

1. Locating all instruments and controls in X, Y, and Z relative to a nominal eye and shoulder point (fig. 2)

2. Developing a sequence of tasks required to complete a procedure from the checklists and operating procedure for the aircraft type (fig. 3)

3. Applying human factors data to the task sequence requirements for reach distances, switch or control actuations, and eye angle changes to develop the task time (fig. 4).

The data for reach times, switch actuation, and eye turn times in the GA-SPIFR study were the same as those used for the original TLA terminal control vehicle data file as presented in the NASA contractor report CR-144942 (ref. 3).

The final product of data development was a detailed task scenario and data file unique to the GA-SPIFR studies being performed by the Stability and Control Branch at NASA/LRC.

4.1.4 VALIDATION RESULTS

The results of the initial TLA data validation efforts for the GA-SPIFR study have been published in NASA Technical Memorandum 78748 (ref. 2). Figure 5 shows an example of one of the validation outputs for this effort.

Basically, the initial outputs showed that the detail task data construction was rational and that the majority of the pilots' time was accounted for. No abnormal workloads resulted from the data structure.

However, it is apparent that the weighting scheme used for the channel called cognition needs to be revised. The original TCV data defined each discrete point as a task impacting only two channels–cognition and one of the other eight channels. The general aviation data defined a task differently so that it could include many discrete points impacting several workload channels. For example, where the TCV program may use six tasks each having one operator and one cognitive channel workload value to define an action; the general aviation data may define the action with one task showing six workload channel values plus the cognitive channel value. Hence, when the TCV cognitive channel weighting scheme was applied to the general aviation duties the cognitive workload was understated relative to the TCV weighting method as workload versus summed by total tasks impacting each workload channel.

4.2 METERING AND SPACING (CDTI BASELINES)

4.2.1 PURPOSE

These baseline scenarios will be used to help study the crew workloads associated with fixed path metering and spacing techniques being used in ATC terminal areas. The scenarios will also be used as baselines to study workloads associated with additional CRT displays of ATC traffic in aircraft flight decks.

4.2.2 DESCRIPTION

There were four baseline detailed task scenarios constructed: two sets each for the Longmont and Byers approaches to the Denver, Colorado-Stapleton International Airport (Denver). In each set, one scenario depicts the crew tasks associated with manual flight control techniques using autothrottle for airspeed control and the other scenario showing the crew tasks associated with flying 2D (ref. 3) autoflight procedures, i.e., the horizontal flight path is prestored in a computer memory and automatically flown by the autoflight system. These also depict autothrottle use for airspeed control.

The outline scenario data for the Longmont and Byers approach to Denver were first created for a program called TAATM (Terminal Area Air Traffic Model). TAATM is a computer simulation of ATC operations configured for a fixed path metering and spacing techniques study being conducted by NASA. (See ref. 4.)

Figure 6 shows the variety of arrival paths to Denver. Figures 7(a) and 7(b) show the Byers and Longmont approach profiles respectively, and tables 1 and 2 tabulate, respectively, the key events and procedures for the Byers and Longmont approaches.

4.2.2.1 Byers Approach

The Byers approach is basically a straight-in approach to Denver. Figure 6 shows a dotted course line deviation from the Watkins intersection. This represents the course deviation that might be needed for metering and spacing purposes. The tabulations of table 1 at times 480 and 524 seconds indicate the course and speed adjustments necessary to obtain the correct spacing for the Byers approach.

Based on the scenario event data, two baseline scenarios were generated: The first was manual flight control using autothrottle, and, the second was a 2D autoflight control profile using autothrottle. The use of autothrottle control in the scenario construction reflects current thinking about future flight control methods. It is assumed that autothrottle will be generally available and used as it will reduce workload.

The Byers approach path is depicted in four phases as described below. In the following description, the computer recognized phase name is given for the manual control (MC) and 2D control flight techniques, i.e., phase name (MC) and phase name (2D).

Figure 7(b) shows a plan view of the approach profile and table 2 describes the event happenings during the approach.

The Longmont approach, like the Byers, provides for course deviations that may be needed for metering and spacing techniques. The course deviation area occurs between NORTH1 and the approach gate shown on figure 7(b). Also, like Byers, there are two baseline scenarios for this approach profile depicting manual and autoflight control techniques.

The Longmont approach consists of six phases which are described below; again the computer name for the MC and 2D flight techniques will be provided in the description.

Phase Type	Description
Descent With Speed Reduction	This phase describes the descent, leveling off, and speed reduction activity required prior to entering a holding pattern at the Longmont intersection. The phase names are LMNT (MC) and LMT2 (2D).
Holding Pattern	This phase details the activities required to enter and fly one loop of a holding pattern. The phase names are HPTN (MC) and HPT2 (2D).
Descent With Speed Reduction	The activities in this phase are basically the same as those of the first phase. The differences are in communications and the length of the phase. The phase names are BRTN (MC) and BTN2 (2D).

Phase Type	Description
Descent	This phase shows the descent activity required to cross the North 1 intersection at the traffic pattern altitude. The phase names are NRTH (MC) and NRT2 (2D).
Descent With Airspeed Reduction	This is the beginning phase showing crew activities associated with leveling off from a descent profile, reducing speed, and returning to descent profile to cross Byers at 3353m (11,000 ft). The computer names are BYRZ (MC) and BYR2 (2D).
En Route Descent	This phase shows a continuation of descent to the WATKINS intersection. The computer names are WTIKN (MC) or WTK2 (2D).
Metering and Spacing Maneuvers	This phase shows the activities required for a course deviation to achieve proper metering and spacing. It also includes speed reduction activities. The computer names are GATE (MC) and GTE2 (2D).
Final Approach	This phase shows the activities involved with flying the final approach course from the outer marker to touchdown. The computer names are BFNL (MC) and BFN2 (2D).

4.2.2.2 Longmont Approach

The Longmont approach represents a more classical traffic pattern including:

1. Holding pattern
2. En route descent profile
3. Downwind leg
4. Base leg
5. Final approach path

Phase Type	Description
Metering and Spacing Deviations	This phase shows the activities required to achieve proper metering and spacing into the traffic flow. Figure 5 shows three possible routes within the area between the North 1 intersection and the approach gate. Currently only the route indicated with the dashed line is described. The phase names are MTRS (MC) and MTR2 (2D).
Final Approach	This phase details the final approach path activities from the outer marker through touchdown. The phase names are LFNL (MC) and LFN2 (2D).

4.2.3 DATA DEVELOPMENT

The data for the Denver studies was developed from the existing TCV data file. The four study scenarios required 20 new phase descriptions, 93 new procedures, and a large number of tasks. Table 3 shows examples of the newly created phases and procedures as derived from the workload analysis worksheet shown in figure 3. (New tasks are not shown as they were spread throughout the data file and are not easily identifiable.)

Due to the extensive number of changes and the nature of the studies, a separate data file was created for the M/S studies. This was accomplished by removing the phase specifications from the TCV data file and replacing them with phase descriptions for the M/S studies. Also, the new procedures and tasks for these studies were entered into this data file. The complete data file is presented in volume 2 of this report.

The primary reason for separating the M/S data file from the original data file was to assure segregated use of the common task data in the two files. Separating the data for the two areas of studies will allow each study group to independently modify task data without impacting the other study. This would not be possible if the two data files were integrated.

4.2.4 VALIDATION RESULTS

The initial TLA validation reports for these scenarios show that the task situations are rational and that pilots' time is well accounted for based on activity channels. The copilots', or first officers' task efforts need to be more completely defined. The outputs depict two measures of workload—the workload histogram and workload summary—and a chronological listing of tasks called the mission timeline. Examples of these reports are provided in figures 8, 9, and 10. Volume 2 shows both the data file and the graphic outputs for the M/S scenarios and the workload efforts can be readily noted, i.e., volume 2 shows the TLA graphic outputs for both the Byers and Longmont approaches resulting from initial scenario validation efforts for both crewmembers and for both approach types.

The preliminary results of these scenario descriptions do not show a large differential in workload between the approach types, manual vs 2D. The small workload differential results from the fact that manual workload primarily consists of control column movements as the B-37 is a "feet-on-the-floor" aircraft. The majority of the workload is derived from the flight and navigation instrument scans. As the flight deck configuration does not change from manual to 2D techniques, the flight/navigation instrument scans basically remain the same. Hence, the major elements of workload remain the same between approach types, while the method of flying the approach changes, i.e., manual versus autopilot.

4.3 FORWARD FLIGHT DECK AUTOPILOT

The original TLA study produced eight detailed task scenarios and analyses to show workload associated with the aft and forward flight decks of the NASA TCV. To extend the earlier TLA effort, a new forward flight deck (FFD) scenario was created to depict workload in the FFD when flight operations include using an autopilot. This scenario profile is identical with the FFD manual workload scenario showing normal workloads.

The aft flight deck (AFD) workload scenarios depicted those tasks associated with using advanced electronic displays and autopilot strategies. Whereas, the FFD depicted workloads associated with using manual flight control and current airline standard flight and navigation instruments.

4.3.1 PURPOSE

The purpose of this scenario is to be able to compare workloads between the FFD and AFD when both flight decks are being operated with the assistance of automatic flight controls. The original eight scenarios were defined to show both nominal workloads, four scenarios, and worst-case abnormal workloads, four scenarios. For more information regarding the original scenarios see references 3 and 5.

4.3.2 DESCRIPTION

This scenario describes operations after takeoff from the International Airport at Atlanta, Georgia, through a climbout, followed by a course deviation to return to Atlanta, a descent, and a final approach. The scenario is identical to the FFD ILS manual flight control scenario. Figure 11 shows a plan view of the FFD scenario from which the autopilot scenario was derived. (Note: The original scenario consisted of 10 phases, six of which were not affected by the use of an autopilot. They were: prestart, start, taxi-out, takeoff, taxi-in, and shutdown.)

4.3.3 DATA DEVELOPMENT

The data required for this detailed task scenario effort was developed from and incorporated into the TCV Atlanta data file. This effort basically consisted of creating four new phases using detailed task data from the existing climb, cruise, descent, and approach and land phases of the forward flight deck manual control scenario. The goal was accomplished by removing the manual flight control procedures from the flight phases of the ILS manual flight control scenario. These edited phases were then renamed and inserted into the data file. The complete TCV data file is presented in volume 3.

4.3.4 VALIDATION RESULTS

The initial TLA output reports demonstrated operability of the new scenario and verified that no data errors occurred. Volume 3 shows the complete TLA report validations for this scenario effort along with the TCV data file. The reports shown in volume 3 are like those shown in figures 8, 9, and 10.

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

Six new scenarios have been created and validated for three areas of research at the NASA/Langley Research facility. These scenarios by study area are:

1. General Aviation

   One baseline scenario depicting the detailed task effort required of a single pilot operating under instrument flight conditions in a high-density traffic area.

2. Metering and Spacing/CDTI Studies

   Four baseline scenarios have been created for use in the M/S studies. Plans are that they will provide a baseline workload for future studies regarding a CDTI.

3. Terminal Control Vehicle

   A baseline scenario for the forward flight deck to provide a comparison of workload efforts for autopilot usage in both the AFD forward and aft flight deck and FFD.

The six detailed task scenarios created during the last phase of the contract have been entered into data files and validated by the TLA program. Initial validation efforts show that the detail task construction for the pilots appear to be rational in that they reflect the demands placed on the pilots. Also, these efforts do not show any instances of abnormally (over 100 percent) high workloads.

All of the new scenario construction data plus the original Atlanta TCV data needs to be validated, i.e., the accuracy of scenario construction techniques needs to be confirmed, refined, and modified, if necessary, to more accurately reflect actual or real world workload data based on real world operations or simulations. Currently, all TLA scenarios reflect workload values based on published checklists and operating procedures and, as such, they are reasonably complete. Nonpublished company communications have not been fully accounted for in the scenarios.

5.2 RECOMMENDATIONS

The TLA program utilizes a general data file consisting of four main segments–phases, procedures, tasks, and subsystems–in which detailed task scenarios are defined by phase names consisting of detailed procedure names. These procedures are in turn defined by detail tasks and their performance requirements. This partitioning of data allows for procedures and tasks to be used in several different situations.

However, when creating new data or modifying data, the partitioning causes problems. As it is currently configured, the TLA program at NASA requires large amounts of tedious data file reading to develop new or modify existing scenarios. This was especially true of five of the six recently created scenarios. The analyst is forced to search many tasks to find one that meets his needs. If the task does not exist, the analyst must then create the task.

The NASA TLA program needs to be refined to reduce scenario construction efforts and increase program utility and analyst productivity. Currently, the capability exists to streamline the TLA program and reduce scenario construction times. This can be accomplished by a front-end program that develops the task times and allocates the channel workload percentages based on the analysts specifications. This front-end program utilizes the geometric data for switch, control, and indicator locations to derive the nominal behavorial times required to perform any given task. The program calculates the reach distances, control/switch actuation times, and eye-angle change necessary to complete the task. Using this capability, the analyst need only submit the order in which tasks are to be performed. The front-end then develops the data that the analyst would have previously developed manually. This results in time savings and enhances the ability to look at many variations of a concept.

This capability could be further extended by developing the capability of TLA to perform interactively. This would allow the analyst the ability to develop a baseline detailed task scenario, then modify it at a computer terminal, and see the results immediately.

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Table 1.—Byers Approach Scenario Key Event Data

Time (Sec)	Position North (nmi)	Position East (nmi)	Altitude meters	Altitude (feet)	Event
Start(0)	-5.74	55.04	4535	(14,879)	Start of Flight Message—"United 24, contact Denver Approach on 128.95"
					Denver Control Response Message—"United 24, proceed to Byers, descent and maintain 13,000"
82	-3.35	47.50	3953	(12,969)	End of descent
104	-2.75	45.09	3953	(12,969)	Message—"United 24, descent and maintain 12,000"
112	-2.56	44.29	3953	(12.969)	Message—"United 24, descent and maintain 11,000"
124	-2.29	43.07	3856	(12,650)	Message—"United 24, reduce speed to 250 knots"
214	-0.62	35.29	3791	(12,437)	Complete speed reduction resumes descent
224	-0.53	34.40	3726	(12,224)	Message—"United 24, reduce speed to 200 knots"
227	-0.53	34.40	3726	(12,224)	Cross Byers Fix
278	-0.44	31.07	3661	(12,011)	End of deceleration, resumes descent to 8,000
434	-0.75	21.55	2429	(7,968)	End of descent
452	-0.73	20.37	2429	(7,968)	Message—"United 24, contact Denver Local Control at 118.3"
480	-0.72	18.71	2429	(7,968)	Message—"United 24, turn right to heading 350 degrees then reduce to normal Approach Speed" (Approach Speed depends on load factor 150 kts)
524	0.55	16.95	2368	(7,770)	Message—"United 24, fly direct to Approach Gate, contact power at Outer Marker on 120.0
862	-0.72	4.17	1981	(6,500)	Cross Outer Marker
976	-0.72	0.33	1627	(5,339)	Cross Runway Threshold

Table 2.—Longmont Approach Scenario Key Event Data

Time (Sec)	Position North (nmi)	Position East (nmi)	Altitude meters	Altitude (feet)	Event
Start(0)	28.08	-34.39	5372	(17,624)	Start of Flight Message—"United 76, Contact Denver Approach Control on 128.05"
					Denver Control Response Message—"United 76, proceed to Longmont, descent and maintain 16,000"
5	28.05	-33.46	5177	(16,984)	Message—"United 76, descent and maintain 15,000"
13	28.03	-32.54	4981	(16,344)	Message—"United 76, hold at Longmont expect further clearance at 16:40" (0 second = 13:49:23 time of day)
45	28.02	-28.91	4641	(16,120)	End of descent
141	27.77	-18.10	4608	(15,119)	Message—"United 76, descent and maintain 14,000"
190	27.61	-12.74	4313	(14,149)	End of descent
229	27.47	- 8.33	4313	(14,149)	Message—"United 76, reduce speed to 250 knots"
265	26.29	- 4.75	4313	(14,149)	Message—"United 76, hold at Longmont, expect further clearance at 16:40:42" (time of day)
286	24.84	- 3.50	4313	(14,149)	Cross Longmont inbound for holding
459	25.19	- 3.63	4313	(14,149)	Depart holding from Longmont
461	24.88	- 3.45	4313	(14,149)	Message—"United 76, increase speed to 220 knots, descent and maintain 11,000"
589	15.44	0.52	3479	(11,414)	Message—"United 76, reduce speed to 170 knots"
646	11.89	1.95	3413	(11,197)	End of deceleration, resumes descent to 8,000
715	8.21	3.40	2852	(9,358)	Message—"United 76, contact Denver Local Control on 118.3"
760	5.92	4.36	2490	(8,461)	End of descent
					Makes RNAV or Map turn toward North 2
837	4.24	7.97	2475	(8,119)	Message—"United 76, fly direct to Altura"
909	1.83	9.88	2170	(7,119)	Message—"United 76, fly direct to Approach Gate"
993	-0.31	6.71	1981	(6,500)	Message—"United 76, reduce to normal approach speed, contact tower on 120.0 at Outer Marker" (Approach Speed depends on load factor 150 kts.)
1053	-0.72	4.12	1981	(6,500)	Cross Outer Marker
1161	-0.71	0.39	1629	(5,345)	Cross Runway Threshold

Table 3.—Examples of New Metering and Spacing Data File

Phase	Description	Proc	Time	Proc	Time	Proc	Time	Proc	Time
	FROM ? GATE THRU	TSP30S	10	160053	10	160018	10	JCLR	10
	TOUCHDOWN	ISC10S	25	160059	30	ISC10S	35	160057	40
		160018	40	ATOLN6	40	160062	50		
		160018	100	ISC90S	115	ATOLN6	140	160065	220
		ATOLND	240	ISC10S	245	ISC10S	255		
LMT2	LONGMONT APPROACH TO	LMNT01	00		00	ISP30S	00	140023	00
	LANDING WITH HOLDING	ISC20S	10	LMNT02	24		30	ISP20S	30
	PATTERN	030007	30	LMNT03	35			ISC20S	40
		ALTCPT	40	LMNT50	45				
				ISP60S	50	030007	100	ISC30S	110
		ISC20S	140		150				
		ISP30S	150	030007	200			ISC60S	210
		LMNT04	220						
		ALT2CH	220		230	ISP30S	230		300
		ISP20S	300	ALTCPT	310	ISC10S	310		320
		ISP60S	320	030007	320	ISC30S	330		
		LMNT05	350						
		AFDSPD	350	ISC20S	400		420	ISP05S	420
		LMNT06	425	AFDSPD	425	LMHLDG	425	ISP05S	430
			435	ISP10S	435				
HPT2	HOLDING PATTERN FOR	LMNT51	00	HLDPTN	00	030007	10	ISC60S	15
	LONGMONT APP BETWEEN	030007	115	ISC60S	120	030007	220	ISC30S	225
	MEEKER AND LONGMNT	ISC05S	255						
BTN2	AIRCRAFT DEPARTS HLD	LMNT52	00	LMNT07	00	AFDSPD	00	ISP15S	05
	DESCENDING TO 11000	030007	10	ISC30S	15	LMNT58	20	ALT2CH	20
		ISP90S	30	030007	45	ISC20S	50	ISC60S	110
		ISP10S	200						
NRT2	AIRCRAFT DESCENDS	LMNT08	00	LMNT53	00	ALTCPT	02	ISC15S	02
	TO 8000 AND SLOWS	AFDALT	02	AFDSPD	05	ISP05S	07	ISP30S	12
	TO 170 KTS	160011	17	ISC15S	27				
		160017	42	160018	42		42	ISP10S	42
		ISC10S	52						
		ALT2CH	52	LMNT54	57	160025	102	160018	102
			102	ISP90S	102	030007	112	ISC30S	117
		ISC10S	147	LMNT09	157	ISC30S	202		
		ALTCPT	232	ISP20S	232	ISC20S	232		
MTR2	NORTH 1 METERING AND	LMNT55	00	TKACHG	00	030007	00	ISC60S	05
	SPACING AREA		10	ISP60S	10	LMNT10	105	030007	105
		TKACHG	110	ISC60S	110		120	ISP60S	120
		030007	210	ISC60S	215		220	ISP10S	220
		LMNT11	225	TKACHG	230			ALT2CH	240
			250	ISP60S	250	140023	255	030007	315
		ISC30S	320	ALTCPT	350	030007	350		
LFN2	FINAL APP TO LANDING	LMNT12	00	LMNT56	00	LNDARM	00	030007	02
	FOR LONGMONT	ISP05S	05	160060	07	ISC10S	07		
			07	ISP30S	07	160053	17	160018	17
		LNDCLP	27	ISP10S	37	ISC10S	47		
		LMNT57	47	LNDCLR	47		47	ISP10S	47
		160059	57	160057	57	160018	57	ATOLN6	57
		ISC90S	107	ATOLN3	157	160065	252	ATOLND	227
		ISC15S	237						

PHASE NAME DESCRIPTION

PROCEDURE NAMES ACTIVE DURING THE PHASE

EVENT/PROCEDURE										
AFDALT ALTITUDE CHANGE PROC	2H	33	0	10	P1	2H	34	1.40	10	P1
AFDSPD AIRSPEED CHANGE PROC	2H	47	0	10	P1	2H	48	1.40	10	P1
ALT2CH ALTATUDE CHANGE PROC	2H	33	0		P1	2H	31	0		P1
FOR 2D FLIGHT PATH	3K	03	0		CP1	3K	04	0		CP1
	2H	34	1.0		P1	2H	28	2.06		P1
	2H	30	2.5		P1	2H	26	3.48		P1
	2K	32	4.5		P1	2H	21	5.93		P1
	2H	22	5.93		CP1	3A	01	6.81		P1
	3L	05	7.41		P1	3H	02	8.01		P1

TASK NAME/START TIME/AND CREWMEMBER EXECUTING TASK

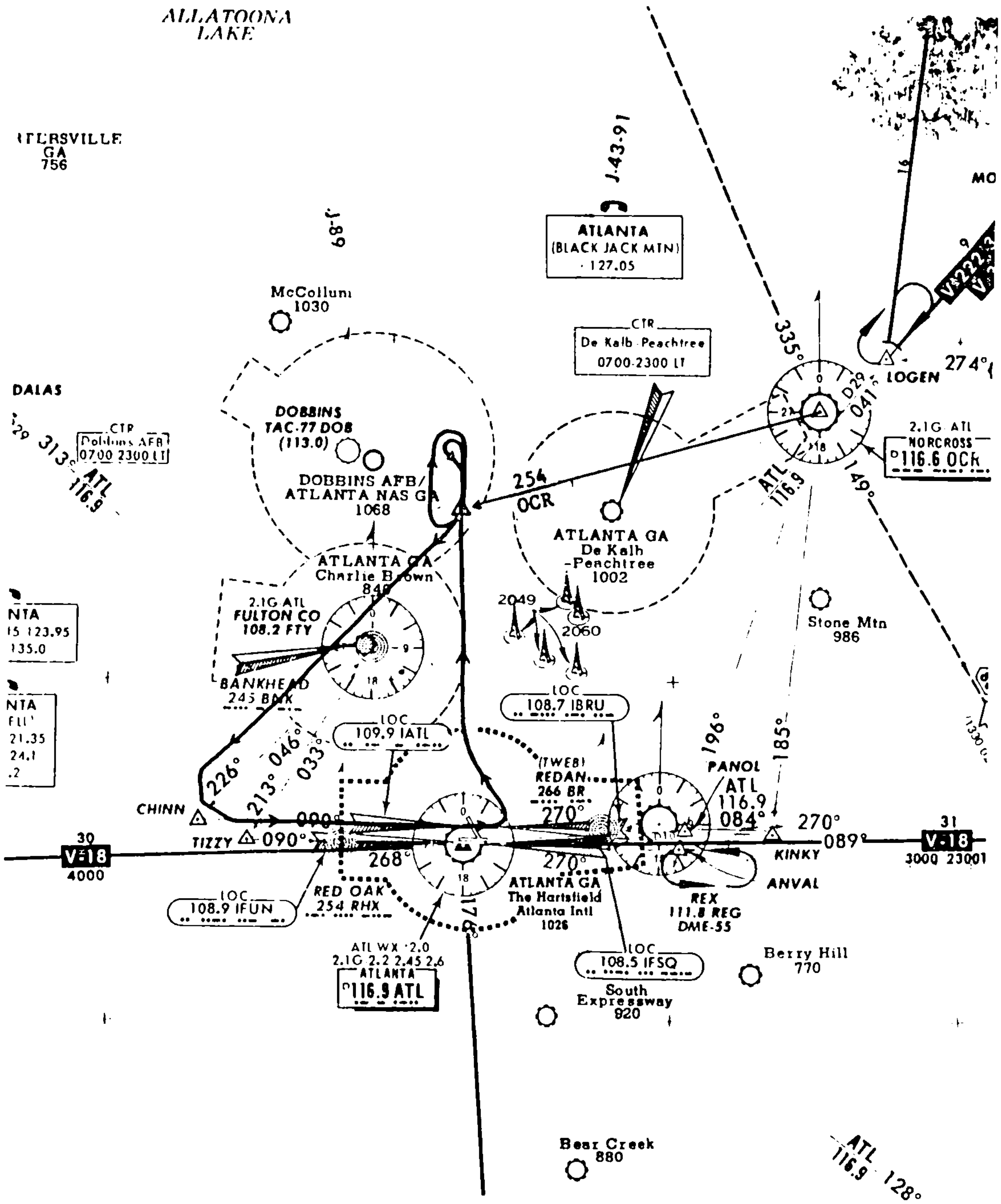

Figure 1.—General Aviation Scenario Profile

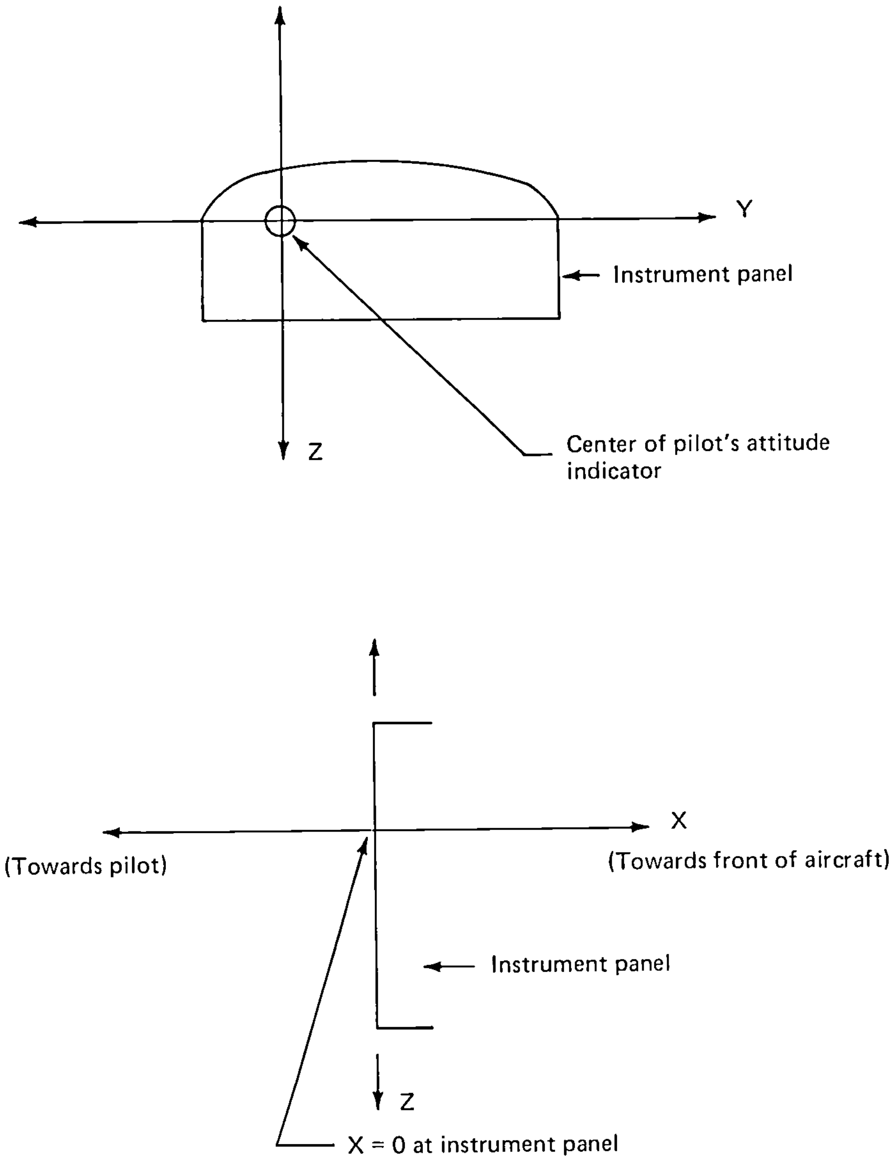

Figure 2.—Coordinate System in General Aviation Simulator

TLA WORKLOAD ANALYSIS WORKSHEET

PAGE____ OF____

MISSION TITLE		CONFIGURATION										
PHASE/EVENT/PROCEDURE DATA		PROCEDURE/TASK DATA										
CODE NO.	NAME/DESCRIPTION	CODE	NO.	NAME/DESCRIPTION	CREW	[illegible]	DURATION SECONDS	START TIME HR.	START TIME MIN.	START TIME SEC.	SLIDE (SECS) -	SLIDE (SECS) +
C00001	CONTACT DEPARTURE AFTER TAKEOFF	1P	01	PICK UP MICROPHONE	P	1	2.0			0.0		
		1P	07	MAKE RADIO TRANSMISSION	P	4	4.0			2.0		
		1P	16	HOLD MICROPHONE	P	4	7.0			6.0		
		1T	28	MONITOR RADIO TRANSMISSION	P	2	7.0			6.0		
		1P	10	MAKE RADIO TRANSMISSION	P	4	6.0			13.0		
		1P	04	RETURN MICROPHONE	P	1	2.0			19.0		
C00002	RECEIVE TRAFFIC ADVISORY	1T	28	MONITOR RADIO TRANSMISSION	P	1	6.0			0.0		
		1P	01	PICK UP MICROPHONE	P	1	2.0			6.0		
		1P	07	MAKE RADIO TRANSMISSION	P	3	3.0			8.0		
		8A	01	SCAN OUTSIDE AIRCRAFT	P	1	1.5			8.0		
		1P	04	RETURN MICROPHONE	P	1	2.0			11.0		
C00003	RECEIVE VECTOR	1T	25	MONITOR RADIO TRANSMISSION	P	1	4.0			0.0		
		1P	01	PICK UP MICROPHONE	P	1	2.0			4.0		
		1P	07	MAKE RADIO TRANSMISSION	P	4	4.0			6.0		
		1P	04	RETURN MICROPHONE	P	1	2.0			10.0		
C00004	REPORT CROSSING FIX	1P	01	PICK UP MICROPHONE	P	1	2.0			0.0		
		1P	10	MAKE RADIO TRANSMISSION	P	2	5.0			2.0		
		1P	16	HOLD MICROPHONE	P	2	2.0			7.0		
		1T	22	MONITOR RADIO TRANSMISSION	P	1	2.0			7.0		
		1P	04	RETURN MICROPHONE	P	1	2.0			9.0		
C00005	RECEIVE REQUEST TO SAY ALTITUDE	1T	22	MONITOR RADIO TRANSMISSION	P	1	2.0			0.0		
		1P	01	PICK UP MICROPHONE	P	1	2.0			2.0		
		1P	16	HOLD MICROPHONE	P	1	1.0			4.0		
		3H	01	SCAN ALTIMETER	P	1	1.0			4.0		
		1P	07	MAKE RADIO TRANSMISSION	P	2	2.5			5.0		
		1P	04	RETURN MICROPHONE	P	1	2.0			7.5		

Figure 3.—Workload Analysis Worksheet

TIME REQUIRED FOR CONTROLLED REACH

Distance, in.	Time, sec	Distance, in.	Time, sec
1	0.324	12	0.570
2	0.372	14	0.574
3	0.402	16	0.624
4	0.432	18	0.648
5	0.456	20	0.672
6	0.474	22	0.696
7	0.492	24	0.720
8	0.510	26	0.744
9	0.522	28	0.768
10	0.540	30	0.792

OPERATING TIME FOR VARIOUS CONTROL AND DISPLAY TYPES*

Control/display type	Average operation time, sec	Reference
Pushbutton	1.04	5
Two-position toggle switch	1.11	5
Three-position toggle switch	1.35	5
Covered toggle switch	1.50	5
Single rotary switch	1.58	5
Rotary switch in an array	1.64	6
Single thumbwheel	1.95	6
Thumbwheel in an array	2.00	6
Hand lever, 5^{o} to 10^{o} movement	1.65	6
Hand lever, 10^{o} to 20^{o} movement	1.85	6
Hand lever, 20^{o} to 40^{o} movement	2.05	6
Hand lever, 40^{o} to 60^{o} movement	2.25	6
Rotary knob	1.69	6
Hand wheel	2.39	6
Discrete indicator	0.25	6
Analog indicator	2.00	6
Digital indicator	0.75	6

*Extracted from references 5 and 6

$$T = \frac{\text{eye angle change (in deg)} \times 0.66 \text{ sec}}{90^{o}}$$

Figure 4.—Human Factors Data Used for Task Time Derivation

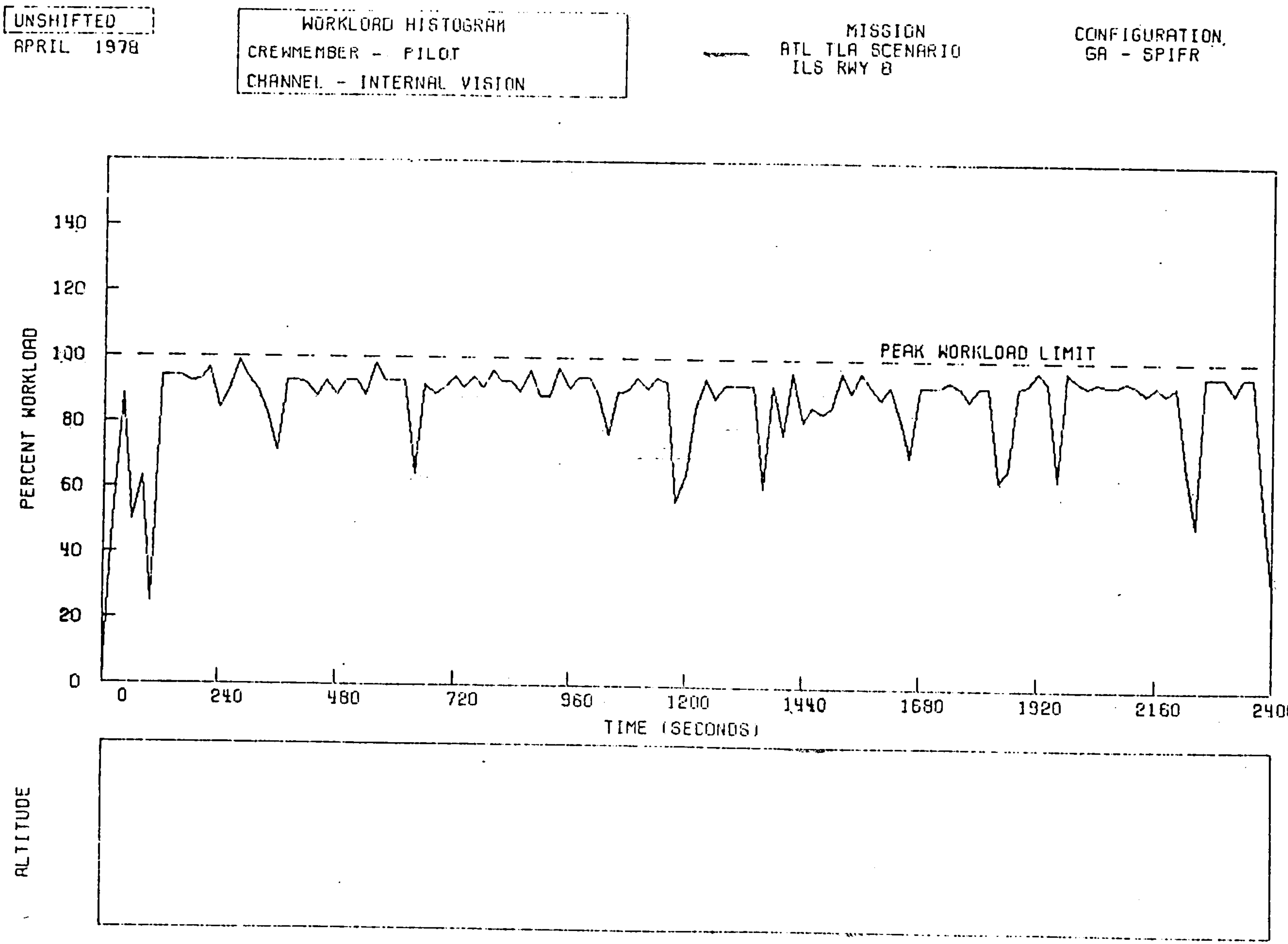

Figure 5.—Internal Vision Workload Histogram Report

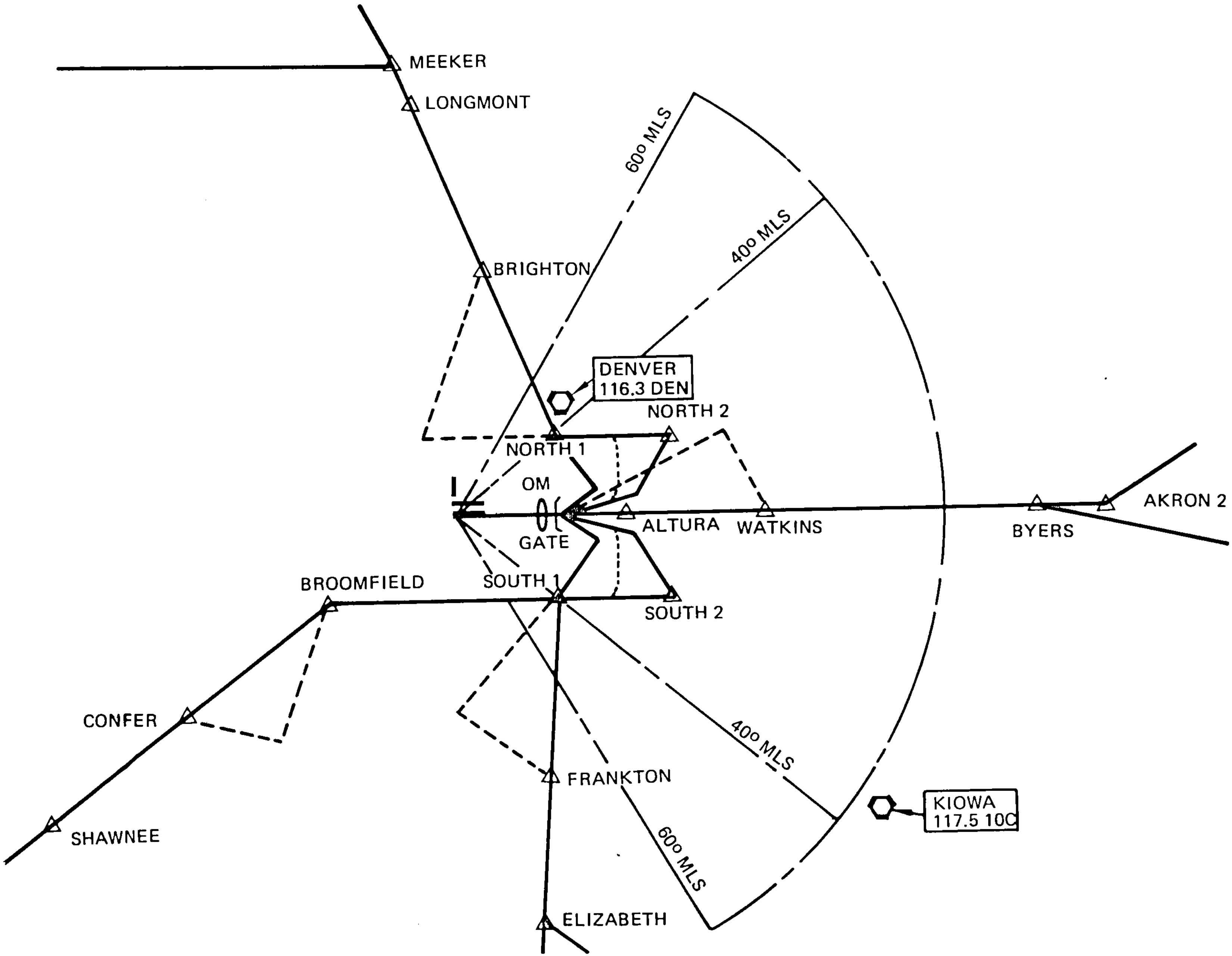

Figure 6.—Denver Runway 26 Arrival Routes

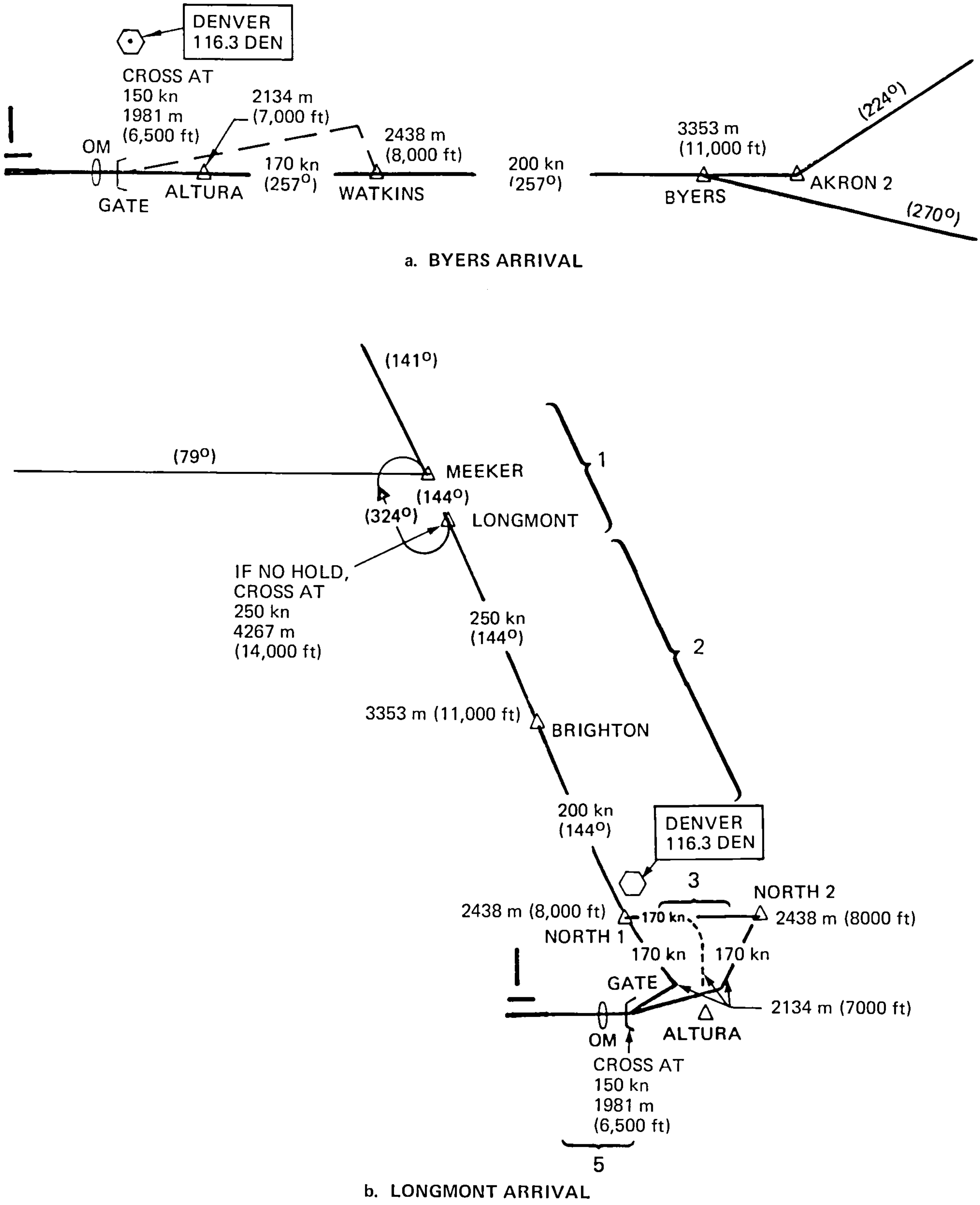

Figure 7.—Fixed Path Metering and Spacing

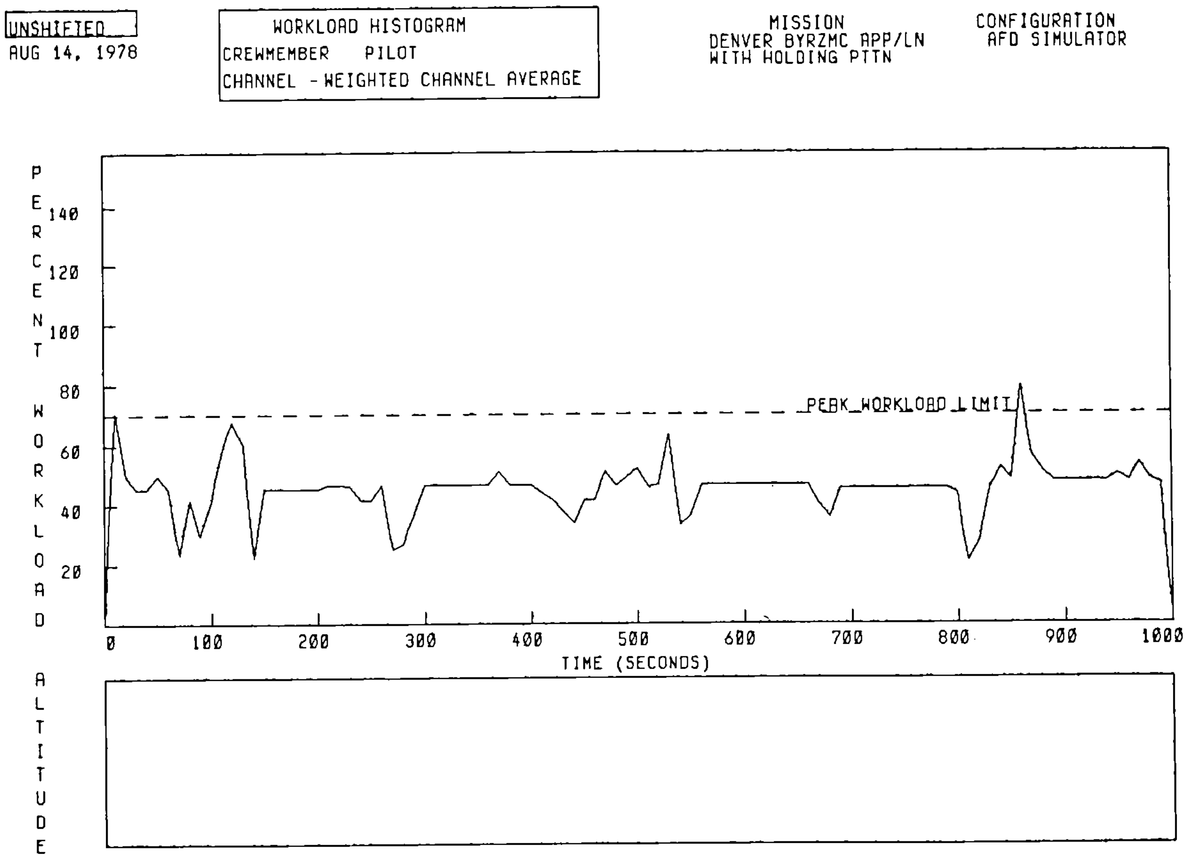

Figure 8.—Workload Histogram

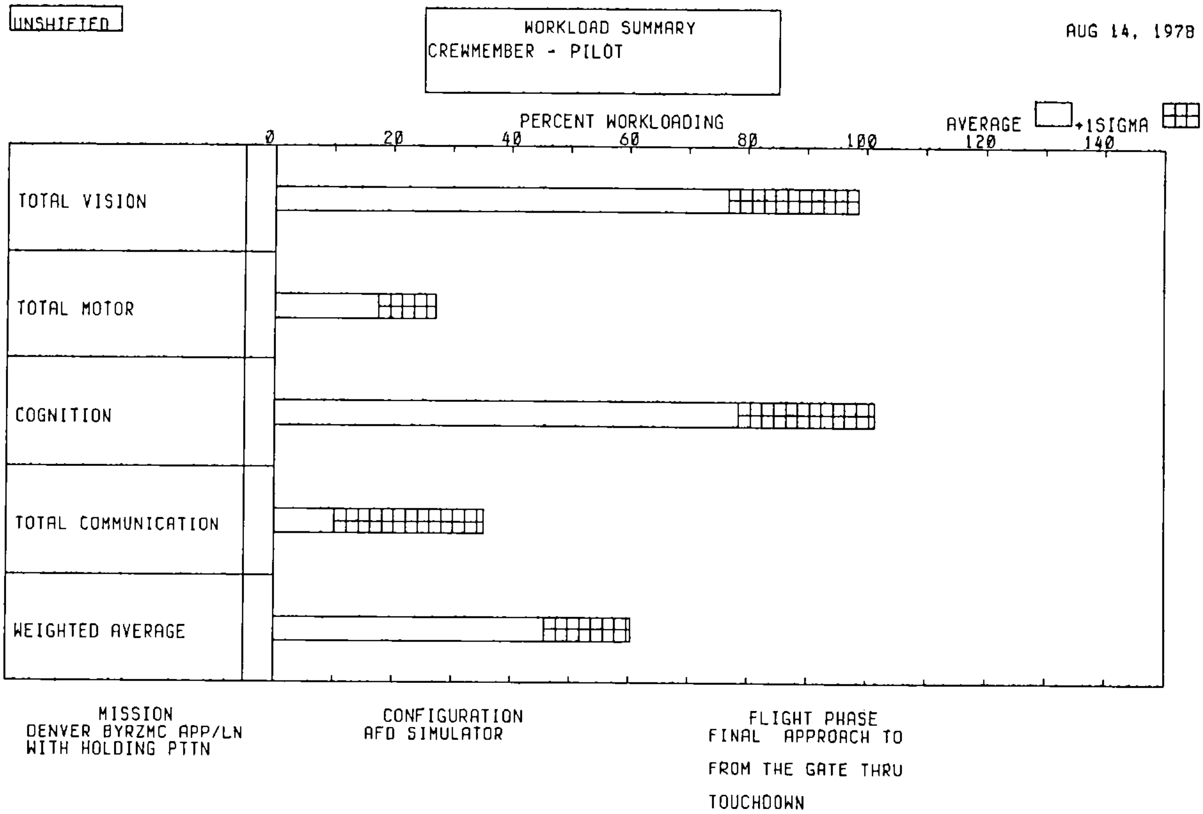

Figure 9.—Workload Summary

UNSHIFTED

MISSION TIMELINE
MISSION - DENVER BYRZMC APP/LN WITH HOLDING PTTN
CONFIGURATION - AFD SIMULATOR
FLIGHT PHASE - BYERS APPROACH TO LANDING FROM ENROUTE CRUISE
CREWMEMBER - PILOT

AUG 14. 1978

CODE	EVENT/PROCEDURE OR TASK DESCRIPTION	TASK DUR (SEC)
BYRZ01	START OF FLIGHT SCENARIO MESSAGE	
MCA60S	CONTROL AIRCRAFT - F (60 SEC PROC)	
ISP60S	FLIGHT INSTRUMENT SCAN - F	
1PBYRZ01	MON COM- UNITED 24. CONTACT DENVER APRCH ON 128.95	5.
4A 65	MANUALLY CONTROL A/C	60.
4B 10	ACTUATE THROTTLES TO ADJUST AIRSPEED	60.
2J 42	MON EADI	60.
3L 02	MON VERTICAL SPEED INDIC	60.
3A 10	MONITOR AIRSPEED INDIC	60.
2K 15	MON EHSI DISPLAY	60.
1PBYRZ03	MON COM- UNITED 24. DENVER, PROCEED TO BYERS DESCEND AND MAINTAIN 13000	5.
140023	REPORT 1000 FT TO LEVEL OFF	
1P 11	MON VERBAL REPORT	1.7
MCA05S	CONTROL AIRCRAFT - A (5 SEC PROC)	
ISP05S	FLIGHT INSTRUMENT SCAN - A	
3A 10	MONITOR AIRSPEED INDIC	5.
2K 16	MON EHSI DISPLAY	5.
4A 64	MANUALLY CONTROL A/C	5.
4B 09	ACTUATE THROTTLES TO ADJUST AIRSPEED	5.
2J 42	MON EADI	5.

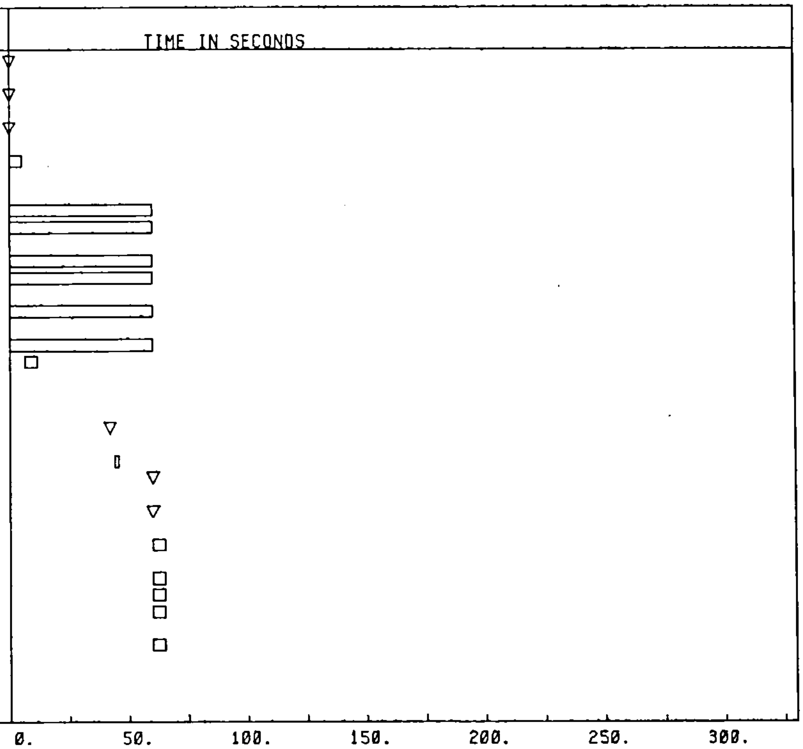

Figure 10.—Mission Timeline

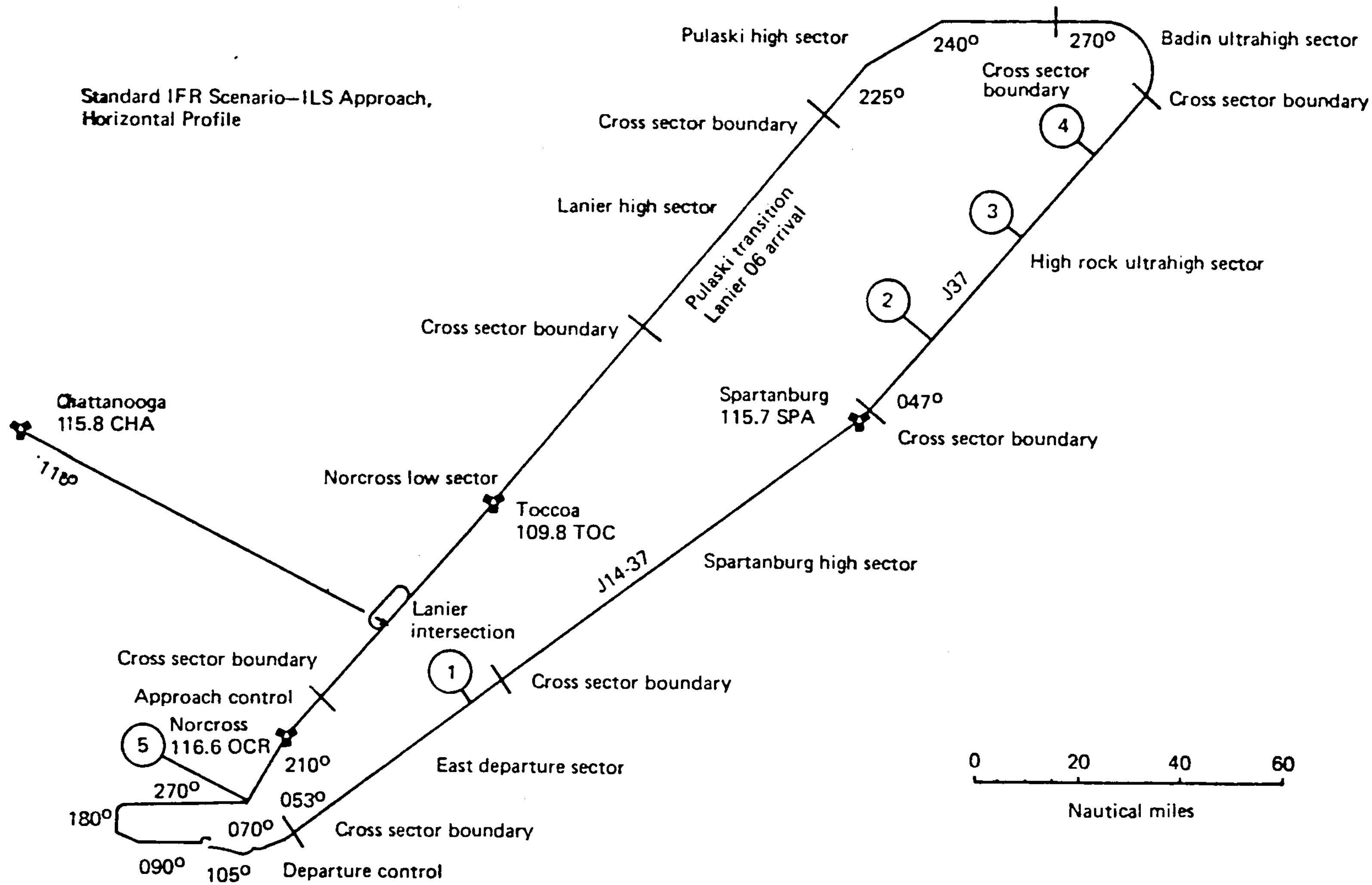

Figure 11.—Forward Flight Deck Scenario Profile

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NASA CR-3199		

4. Title and Subtitle	
NASA TLA Workload Analysis Support Volume 1 - Detailed Task Scenarios for General Aviation and Metering and Spacing Studies	5. Report Date March 1980 6. Performing Organization Code
7. Author(s) James L. Sundstrom	8. Performing Organization Report No. D6-32872
9. Performing Organization Name and Address Boeing Commercial Airplane Company P.O. Box 3707 Seattle, Washington 98124	10. Work Unit No. 11. Contract or Grant No. NAS1-13741
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, D.C. 20546	13. Type of Report and Period Covered Contractor Report 14. Sponsoring Agency Code

15. Supplementary Notes

Langley Technical Monitor: Amos A. Spady, Jr.

Topical Report

16. Abstract

This document reports on the efforts and outlines the techniques required to produce and validate six detailed task timeline scenarios for crew workload studies in the areas of:

a) General aviation single pilot instrument flight rules operations in a high-density traffic area

b) Fixed path metering and spacing operations

c) Comparative workload operation between the forward and aft-flight decks of the NASA Terminal Control Vehicle.

The validation efforts also provide a cursory examination of the resultant demand workload based on the operating procedures depicted in the detailed task scenarios.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
Task scenario, General aviation single pilot timeline analysis, Crew workload, Metering and spacing, TCV	Unclassified - Unlimited Subject Category 53

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
Unclassified	Unclassified	36	$4.50

*For sale by the National Technical Information Service, Springfield, Virginia 22161