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DEVELOPMENT OF A SYSTEMS THEORETICAL PROCEDURE FOR THE EVALUATION OF THE WORK ORGANIZATION OF THE COCKPIT CREW OF A CIVIL TRANSPORT AIRPLANE

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Translation of: "Entwicklung einer systemtheoretischen Vorgehensweise zur Beurteilung der Arbeitsorganisation der Cockpit-Besatzung von zivilen Transportflugzeugen" Technische Universitaet, Berlin, Institut fuer Luft- und Raumfahrt, Berlin (W. Germany), Final Report, May 1983, pp. 1-145.

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16. Abstract

For an optimum design of the man-machine interface with aircraft, a description of the interaction and work organization of the cockpit crew is needed.

The goal of the project is to develop a system-theoretical procedure to permit an evaluation of the work organization of pilots while structuring the work process.

To simulate sequences of pilot actions on the computer, statistical data is needed which can be obtained from tests on the flight simulator. Investigations of computer simulation and a discussion of their applicability for evaluating crew concepts is also provided.

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Summary

For an optimum design of the man-machine interface with aircraft, a description of the interaction and work organization of the cockpit crew is needed in addition to an analytical description of the operations of the pilots.

The work organization for pilots in civil transport aircraft is specified in crew-concepts which are generally developed empirically and checked.

The goal of the project is to develop a system-theoretical procedure to permit an evaluation of the work organization of pilots while structuring the work process.

The requirements of work organization are worked out which result from the influences on the cooperation of small work groups. The fundamental structures of present crew concepts are then compared to these requirements.

Besides the preparation of basic procedures to develop a method of evaluation, existing descriptive forms for illustrating action sequences and decision-making processes are checked for their applicability to the evaluation process. From this, a rule is developed for describing the work sequence in the cockpit.

To simulate sequences of pilot actions on the computer, statistical data is needed which can be obtained from tests on the flight simulator. Investigations of computer simulation and a discussion of their applicability for evaluating crew concepts is also provided.

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1. Introduction /1*

In addition to the work division between man and machine, the workspace and work process structure are important considerations in the design of a man-machine system. If several operators are included in the work process, then organizational guidelines are usually specified to support a smooth, safe and effective flow of work. For instance, in the area of civil aviation, the tasks of a cockpit crew are specified by so-called crew concepts. They contain the allocations of tasks and responsibilities and guidelines for communication within the crew and specifications for individual action-sequences (procedures).

With the design of new aircraft cockpits and the incorporation of new cockpit systems, the work division between pilot and aircraft is generally changed, so that a change in the work processes and thus in the crew concepts become necessary.

The coming aircraft generation will be distinguished by far-reaching changes and expansions of cockpit systems /13, 37, 48/. The increasing requirements of economy, flight-control accuracy and aircraft safety will be met in the cockpit area through digitalization of systems, increased use of on-board computers and a reduction in the cockpit crew /2, 4, 5, 12, 28, 43, 49/. In this case, new technologies will come into use, especially in the area of display-control elements /37, 39, 48/. The technical and operational changes will affect and activity or task-range of the pilots.

Besides their new role as system manager, the pilots will be assigned additional tasks if the crew size is reduced.

Thus the division of tasks and responsibilities within the crew will have to be re-designed.

Thus, a method of evaluation is needed which will permit a check during the aircraft development stage, of the proposed cockpit design and of desired procedures to determine the capabilities and safety of the selected work organization.

*Numbers in the margin refer to pagination in the foreign text.

The work organization of the cockpit crew of civil transport aircraft has been developed empirically. Checking of the capabilities and safety of the concepts was performed under the assumption of normative pilot behavior. Investigations of aircraft accidents have shown however, the concepts defined in this manner can still lead to strings of incorrect actions and to an overload of the pilot /25, 26, 47/. /2

The method of evaluation under development should check the work organization of cockpit crews of civil transport aircraft with regard to their capabilities and safety. In particular, time task-pileup and conflict situations should be recognized and the work load of the individual crew members should be determined. Furthermore, the safety limits of the crew concepts should be determined for non-normative pilot behavior.

The procedure for developing an evaluation method is presented in fig. 1. The method will first be evolved for a representative example and finally it will be applied in a larger framework for its applicability to existing crew concepts and validated. Selection of a crew concept and of a flight task for the example, is followed by a task analysis of the pilot actions to be performed in the example.

Development of the evaluation method is organized into two phases. First, the selection and testing of decision-making forms in order to present crew actions on the computer for the selected example. After its completion, the descriptive forms shall be used as a working means for the evaluation process in order allow a check of the action-sequences and events in the cockpit based on a Monte-Carlo simulation.

The descriptive forms shall be used to simulate action sequences and decision-making processes. Reference will be made to existing theorems for illustration of such activities, from which the theorems used for the evaluation method will be selected or worked out.

In order to check the capability and reliability of the selected theorems, a simulation of crew activities is performed on the computer. Statistical data on the reaction and manipulations times for the individual pilot tasks will be needed for this. This statistical data can be obtained from measurements on a flight simulator. /3

The tests on the flight simulator pertain to the flight task and crew concept selected for the example. They also serve for determination of the statistical data for a determination of the work sequences in the cockpit, which are to be compared with the computer-simulated work sequence.

Results are expected from this comparison which will lead to a modification and improvement of the selected descriptive forms.

In the second phase of the proposal, an evaluation method will be developed from the existing, descriptive theorem. This includes first the development of evaluation criteria, the potential conflict situations, overloads on individual crew members and recognition of danger situations. The descriptive forms to simulate the action sequences are predicated upon quantitative specification of evaluation criteria.

The computer simulation prepared in the first phase of the outline initially provides only for a description of activities inside the cockpit. But to view the entire process, the mutual interactions of crew members and of the flight control process must be taken into account. In order to be able in principle to account for all possible events during the flight for an evaluation of the work organization, a corresponding, extensive test program must be provided for the computer simulation.

Information is expected on the applicability of the method as an aid in the design of crew concepts and in the evaluation of the effects of non-normative pilot behavior on the work process.

2. Specification of Cooperation of Cockpit Crews Through Crew Concepts /4

An efficient and reliable execution of flight tasks is predicated on an effective work performance of the cockpit crew. The cooperation and capability of the crew is determined by the systems available in the cockpit, the level of automation, legal and operational specifications. In addition, the individual capability of pilots and the work organization in the cockpit will affect the work performance of the entire flight team (see fig. 2.1)/25, 38/.

By changing these parameters, an increase in the work performance and an increase in the safety of the entire system can be achieved.

Therefore an attempt was made to draw conclusions from accident investigations which would lead to actions for improving the capability and reliability of the crew. Furthermore, the potentials to improve cooperation with pilots were discussed /20, 26, 40/. It was found that possible solutions, like training, standardization, regulation and development of procedures do contribute to safe work and performance of the individual pilots, but have little effect on cooperation of pilots and on effectiveness of crew actions /25/. The individual work performance of the individual crew member contributes only to a slight extent to the performance of the entire team /22/. Therefore, a change in the task structure of the pilots and the development of precise, standardized crew-responsibility criteria is proposed /25/.

This led to the development of work organizations for the crew which are summarized into so-called crew concepts. Aspects to be taken into account in the development and revision of such concepts are presented below. Next, an overview of the basic structures of existing crew concepts is presented.

From this, the considerations needed to evaluate crew concepts are worked out and the requirements of an evaluative method are specified.

2.1 Influences on Cooperation Among Pilots /5

A smooth cooperation of the pilots is a fundamental prerequisite for the safe completion of the mission, especially in operating phases having a high task-density. The increasing transport density, complicated flight safety regulations and noise-reducing approach and departure methods place high demands on the flight accuracy of the aircraft and thus on the capability of the cockpit crew. With the introduction of new navigation aids, like e.g. the MLS, curved and variable approach paths will further increase demands on the pilots.

The number of tasks to be performed by the pilots requires a precise coordination of their activities. This coordination must take place within the crew and between ground requirements and environmental events to harmonize with the work process in the cockpit. In order to assure the safety of the system, this coordination may not overwork the pilot, but must be clearly specified.

In /25/ reasons for an ineffective crew performance are given which lead to near-misses or accidents. These are primarily problems affecting the role and relations of the pilots, problems due to changing tasks, division of execution and responsibility for actions and the indifference of crew members to regulations. Thus, in the work organization of the cockpit crew, the work division, allocation of responsibility and basic rules of communication between pilots must be specified. The capability of the crew is greatly affected by this work organization.

In the development of work organizations the influences on this pilot cooperation and on the crew capability must be taken into consideration first.

A basis for a high-performance work of the pilot team is an optimum cooperation between man and machine. Ergonomic and anthropotechnical considerations, like cockpit architecture, design of display and control systems and level of automation, must be taken into account.

In addition, operational and personal considerations, and /6
the properties and relations of the particular tasks are pertinent to pilot cooperation.

In /22/ an overview is given of the important parameters affecting the cooperation of several men in a working team and the effectiveness of that team.

A team or crew is defined as a well-organized and a well-structured working group subject to relatively formal action-sequences. This definition also applies to the cockpit crew of aircraft. Parameters affecting the work performance of the group are:

- the number of crew members
- the crew organization
- cooperation and
- composition of crew members.

2.1.1 Number of Pilots

The number of crew members affects the potential organization and cooperation. As the number increases, a coordination of actions is impeded /22/. For smaller groups, like e.g. in the cockpit, the size of the crew is determined primarily by the properties and structure of the tasks to be performed.

The cockpit design is also important here. Through local allocation of cockpit systems, allocation of tasks to crew members can already be specified and thus the work organization is affected. A relatively large number of crew members also causes a local separation in the cockpit. Thus, the pilots can get an overview of the entire available information. Furthermore, the mutual monitoring of crew members is impeded and the redundance and safety of the system is reduced. For instance, in a 3-man crew of standard arrangement in the cockpit, a mutual monitoring of the pilots and monitoring of the pilots by the flight engineer will occur. But the pilot is not able to monitor the flight engineer /26/. /7

If the crew size is reduced, the pilots will have to take on more tasks, but communication and monitoring problems will be simpler /16/. An excessive work load on the pilots must be counteracted by a higher level of automation of cockpit systems. This can be done e.g. by development of intelligent warning and control systems. With a reduction of the crew there will be less space available for installation of display and control elements, due to the action-space of the pilots and this will require a redesign of the cockpit and of its systems. The increase in the effectiveness of crew performance and economy of aircraft leads to the specification of the so-called Minimum Operating Crew. For example, in spite of the high development costs, efforts are underway aimed at a 2-man crew in future commercial aircraft in order to reduce direct operating costs /49/.

The specification of the Minimum Operating Crew must be taken into account right in the aircraft proposal stage. It is directly related to the development of the work organization of the pilots since both are needed to check the safety of the overall system via activity analyses, time and motion studies and stress measurements. Through the establishment of the minimum operating crew, the composition and placement of cockpit systems is also affected which can cause an 'a priori' specification of the crew work division. The number of crew members and the resulting spatial distribution in the cockpit directly affects the potentials for communication and monitoring guidelines to be specified in the work organization.

2.1.2 Work Organization

The organization of the crew members describes the relations between the tasks or activities to be performed, and the operators /22/. Included herein is the specification of responsibilities of the individual crew members for individual tasks or activities and the responsibility for correct execution of said tasks.

Knowledge of the organization of a working group permits a quantitative prediction of the work performance of the group, provided the particular tasks and task-relations are also known /22/.

The work of the pilots and the performance of the crew is /8
determined primarily by the specifications from the organization of the crew. An effective, safety-promoting work of the crew can only exist when the regulations of the work organization are followed, when they provide clear instructions for all situations and do not overload the pilots.

A non-normative behavior of the crew can be attributed to excessive workloads on individual crew members, to the indifference of the pilots to regulations and ambiguity in task allocation. Such ambiguities appear especially when activities and responsibilities are assigned to different crew members, e.g.

- for command responsibility of the pilot when the co-pilot is flying, or
- for the responsibility of the flight engineer when the pilot deviates from prescribed procedures /25, 47/.

In addition, a non-normative behavior of the pilots is expected when danger situations occur which cannot be countered by following acceptable procedures /18/. There can be two reasons for this relative to the crew organization.

First, the work organization can have caused the emergency situation through ineffective monitoring guidelines and absence of redundance leading to several incorrect subtasks, and by not providing clear instructions for the emergency situation.

Second, the work organization can prevent a timely solution to the problem before occurrance of the emergency situation through stringent regulations and a lack of flexibility.

The flexibility of crew members in following the work organization is viewed as very important for normal situations /22/. It allows non-normative sub-actions to be corrected quickly within the normal, normative procedures.

In addition, a too stringent work organization in normal situations would increase the probability of pilots not following the regulations /22/. But in emergency situations a strict and very accurately defined work organization is needed since one generally cannot expect the pilot to get an overview of the precise extent of the error in the very little available time and to be able to select the correct reaction.

2.1.3 Cooperation of Crew Members /9

The cooperation of group members is the most important characteristic distinguishing a working group, crew or team from a group of individual operators /22/. This cooperation includes all interactions between crew members, mutual information, coordination and joint or coordinated action. Whereas the coordination of actions is governed primarily by the work organization (see sec. 2.2), information and communication are the parameters under consideration here which affect the capability of the team.

Often a working group is described as having particularly good cooperation based on their capability, and additional, not-precisely defined properties of the group members are included in this concept. The concept of cooperation should thus explain the phenomenon that certain working groups are more capable than other groups under the same communications guidelines and the same work division. The reasons for this could be called "motivation," "better understanding of group members for each other" or "better adaptivity of members to the group."

But these cannot be clearly defined and are usually individually founded factors which subtract from a systematic and general regulation by specifications or training procedures.

The systematic influencing of the capability of a crew by improving the cooperation is thus possible through the regulation of communication and information guidelines.

This regulation is all the more needed, the more the tasks of the crew members depend on each other by content or time. The simultaneous, direct influence of the flight process by the pilots requires an extensive, mutual information. A sufficient safety can only be obtained when each pilot is informed not only about the entire system status, but also about the activities and intentions of the other crew members.

For a secure transmission of usually verbal information in /10 the cockpit, redundant communication guidelines are needed. Since the work division of the pilots and the division of responsibilities are variable in many cases and can be exchanged by the pilots, unequivocal guidelines and transferral specifications are needed.

The communication guidelines should make sure that they permit not only contentually unique and redundant information flow, but also cover any occurring misunderstandings and inattentiveness of crew members which may yet occur.

2.1.4 Composition of Working Groups

The composition of working groups differs e.g. by sex, age, race, ability, education, experience and personality of the individual crew members, and by the type and distribution of these characteristics within the team. In addition, there are factors arising from the time-duration or stability of such compositions /22/.

The influence of these parameters has evolved over the years particularly with regard to the composition of older, more experienced aircraft pilots with young, newly-trained copilots and has been recognized as a safety hazard /44/. It was also superimposed by a role misunderstanding of many, older air captains /45/. The influence of such individual parameters on the capability of the crew must be suppressed by appropriate schooling and attitude training of the pilots since the work schedules and rotation regulations constantly cause a change in the composition of the flight crews, particularly in large airline companys. The individual characteristics of the pilots must therefore be suppressed in favor of interchangeability and in favor of a uniform capability in each team composition.

2.2 Overview of the Structure of Present Crew Concepts /11

The role assignment of pilots in the cockpits of civilian transport aircraft has been subjected to a severe change in recent years. Whereas before the command of the aircraft was solely in the hands of the flight captain, and co-pilot and flight engineer were relegated to the role of "hand-extenders," efforts today are aimed at a uniform distribution of tasks and responsibilities in the cockpit /44/.

Such a distribution is necessary since the number of tasks for efficient and safe operation of the aircraft, the complexity of modern on-board systems and the requirements of flight accuracy will overload the work capacity of a single pilot.

Detailed flight accident investigations and stress studies indicate rather, that a uniform distribution of the workload to the entire crew in all flight phases, standardized distribution of responsibilities and precise specification of relations between the crew members are absolute requirements for the safe operation of the aircraft /29, 40/. Furthermore, optimum procedures, a coordination of crew actions and well-structured checklists are viewed as necessary to maintain safety /26/.

The new role distribution resulting in the cockpit provides for the coordinated cooperation of crew members with equal rights /30/. It presumes that all crew members are aware of the entire sequence of the flight command process at all times of the flight /26, 45/. Furthermore, each crew member is also required to perform his own work and monitor the actions of the other crew members and to report any striking abnormality in the system /45/.

Mutual monitoring of flight captain and copilot is considered unproblematic, since both are busy in close cooperation with the same tasks of aircraft command. But the implementation of monitoring of the flight engineer by the pilots is more difficult

since the former is busy with other tasks and usually sits behind the pilot. The monitoring of the flight engineer by a pilot means that the pilot must simultaneously leave his field of effort /12
/26/.

A coordination of crew activities should also prevent a series of situations recognized as potential sources of accident. For example, at all times at least one pilot should observe the most important aircraft status readings. Both pilots thus should never perform tasks simultaneously which divert them from aircraft command /40/. Possible solutions to improve the work performance and safety in the cockpit are the definition of work organizations with work division, communication and coordination guidelines and training on flight simulators specifically for pilot cooperation.

Concepts for tasks and roles of crew members currently prevailing in the air transport companys generally provide for two parallel structures in the cockpit:

the so-called "command-line" and the "functional-line." The functional-line assigns the crew members to their position in the cockpit. They are generally designated as CM1, CM2 and CM3 (CM = crew member), with positions

CM1: front left
CM2: front right
CM3: rear (on system panel).

The command-line is defined as:
Captain (pilot in command = PIC), First Officer, System Officer /1/.

The pilot in command bears responsibility for command of the entire mission and coordinates the work sequence in the cockpit, regardless of the sometimes alternating action-responsibility for individual tasks. The allocation of tasks to the individual crew members differs for the pilot flying (PF) and the pilot not flying (PNF). The roles of the PF and PNF are interchangeable between CM1 and CM2 /44/.

The goal of this division is to assure full use of a pilot for the primary task of flight command /10/. The precise assignment of individual tasks and activities to the roles of PF and PNF are different for each aircraft type and in every airline company.
In addition, the various guidelines of the company instruct the /13
pilots in a corresponding allocation of roles of the PF and PNF to the positions CM1 and CM2 for different flight phases. For the assignment of individual activities to the areas of responsibility of the PF and PNF, an analysis of all tasks performed in the various flight phases and their breakdown into "specific behavioral objectives" is available /45/. "SBOs" represent attainable task-goals through precisely defined conduct and specified activities. These activities can finally be assigned to the crew members with consideration of specific guidelines /1/.

The resulting, general work divisions are presented in the tables in figures 2.2 and 2.3. The precise assignment of individual tasks to the crew members is found in the appropriate handbooks /6, 10, 11/.

The cockpit design of future transport aircraft is distinguished by extensive digitalization of systems, new technologies for display and control elements and by a desired reduction in the cockpit crew /48/. If the flight engineer remains in the cockpit, a change in his seated position with a view forward (FFC--forward facing cockpit) is suggested /12/. The systems observed by him will be integrated into the front panels or into the overhead panel.

Whereas a better, mutual monitoring of crew members will be achieved compared to the existing arrangement in the cockpit, the newly developed on-board computer systems represent a work capacity which could permit a reduction to the two-man crew /12/. The safety and reliability of both concepts will have to be demonstrated by a differentiated investigation of the procedures developed for them. In addition, the effects of the new technology on the workload on the pilots and on the entire work process will have to be taken into account.

The statements of various airline companys on the structure of the work of their pilots in operational aircraft are based on the same prerequisites, but differ in the method of their evolution. For example, the work division resulting from the crew /14
concepts is described in detail in the flight operations handbooks /6, 10/, a presentation of the principles underlying the work organization has only been found in /1/.

In /27/ there is an overview of the approach method specified for US airline companys with reference to the pertinent crew-coordination concepts.

The goal of the work organization is a clear and balanced distribution of tasks to the members of the cockpit crew.

In order to promote an orderly cooperation, mutual monitoring and support of crew members, in /10/ guidelines are presented for communication of pilots and for delegation of tasks, in addition to the work division presented in fig. 2.3.

Since the pilot flying assumed direct command of the aircraft, the pilot not flying will have to do all additional, needed switching tasks after being requested to do so by the PF. While the PF performs the control of the aircraft and the thrust control, the PNF upon instruction, must set the flaps and spoiler, lower the landing gear and select radio speech and radio navigation frequencies.

The delegation of such tasks is subjected in /10/ to a formalism which is to assure the timely and proper execution.

With a verbal confirmation of a request, the assigned crew member assumes responsibility for execution of this task. He is thus obligated to perform the action and to check the success of the action based on the appropriate indicators. Finally, a report is made that the task was completed. This confirmation requires the tasking member to check the action again /10/. The communication between pilots prescribed for the delegation of tasks thus provides for verbal confirmation and completion reports. This principle of two-way communication /44/ should assure that the tasked crew member completes the requested activities as "conscious action." This includes also a check of whether the required action can be performed under the particular system status.

The introduced guidelines for work division, coordination and communication of crew members form a valuable framework for a safe and capable cooperation in the cockpit. But the application of these guidelines to the individual activities, flight phases and situations is decisive for the reliability of the system.

In the transfer of crew concepts to the procedures for pilots using the example of the approach flight, four different principles are found in the literature (fig. 2.4) /1, 4, 27/.

From the different distribution of responsibilities for actions and overall responsibility for the flight, conflict situations can develop.

Besides the responsibility for the entire mission, the pilot in command has to make the decision on continuing the landing or performance of the "go around" procedure. The most important criterion for his decision, namely the identification of the runway, is provided by the copilot (principle 1). In another case he can perform this task entirely alone, but has no direct influence on flight command, since the copilot is flying the aircraft (principle 2).

In addition, in both cases the pilot flying by instruments must switch to visual approach in the middle of his approach flight. Besides the adaptation to external visual conditions connected with this, the tendency of pilots to switch to visual approach as soon as possible exerts a dangerous influence /29/.

On the other hand, conflict situations can arise when the copilot as PF guides the aircraft and recognizes that the PIC is making wrong or hazardous decisions. Here the action-responsibility of the PF is opposed to the command responsibility of the PIC.

The third principle attempts to go around these conflicts. But here the difficulty appears that the flight command task has to be transferred in the middle of the terminal approach which again requires an adaptation phase.

In principle 4, the transfer of aircraft command is taken into account. But here a continual flight implementation by instruments is assured beyond the landing decision. The parallel /16 and equally-authorized decision authority for the landing decision can also lead to conflicts in connection with the overall responsibility of the PIC. The examples presented here pertain to manual aircraft command which is not used in most cases of normal flight performance, but is needed in system failures. But in the exceptional cases or emergency situations such conflicts have a particularly severe effect.

In addition, in viewing the work organizations one must take into account that to prevent or recognize errors, checking tasks, confirmation and reporting methods have to be introduced. Failure to follow these procedures by the pilots or their lax execution in phases of higher workload could lead in chains to danger situations which are not recognized by the pilots in time.

The emergency procedures minimized and strictly organized for emergency situations are only applicable to a few, precisely defined emergency situations. Therefore one must check whether the pilots can come out of dangerous situations without having to leave the normal, prescribed procedures.

Emergency situations, wrong reactions and decisions occur generally due to pilot overload. This overload should be prevented by a uniform task distribution defined in the work organization.

The preparation of time budgets for the pilot actions is not sufficient for estimating their workload. Such time budgets do not point up individual, short task pile-ups which lead to load peaks. Such task pile-ups necessarily occur when the actions of crew members are interrupted by requests via radio or e.g. during the approach when clearance is changed and a new approach has to be prepared in the shortest time due to high traffic density.

The procedure described in /45/ for development of work division via SBOs and the prerequisites described in /1/ presume that a work organization is being proposed for an already existing cockpit. With the specified positions of display and control elements in the cockpit, certain allocations of tasks are specified 'a priori' without an optimization of the procedures being possible. A useful development of the work division for the pilots must be performed in connection with the cockpit proposal in order also to assure potential access to the positioning of cockpit elements.

3. Selection of Descriptive Forms

The cooperation of the pilots in the cockpit is affected by the specification of work organization with regard to work division, action sequences, coordination and communication of crew members.

But the crew concepts provide no guidelines about the type of implementation of individual tasks. From this result the requirements for descriptive forms to be used for the evaluation of work organizations.

The descriptive forms must permit primarily the illustration of action sequences under consideration of specified guidelines on work division and coordination. Furthermore, they must be able to describe the effects of certain system states or actions on the work process of the pilots. Since the theorems to describe the work sequence in the cockpit are of prime importance for the evaluation method, the description and simulation of effects on the flight status and flight command process are not considered in this chapter. The description of effects of crew actions is only taken into account here when we are dealing with decision processes which directly affect the course of the work process in the cockpit.

The previous development and evaluation of crew concepts takes place via time-line anayses which determine the workload on the pilot via the determination of time budgets, in addition to a detailed task analysis.

The goal of the time-line analysis is to determine the workload on operators in complex man-machine systems and the capability of the entire system /17/. The analysis provides for the determination of all execution times of task elements of the operators in order finally to compare by a simulation, the time span available for a specific mission with the time span needed for performance of that mission. The procedure and a program for implementation of time-line analysis are described in /23/ and /24/ for evaluation of the workload on pilots.

The time-line analysis represents a very detailed investigation of the activities in the cockpit. With the precise breakdown of individual tasks down to individual motions of the pilot, the needed time can be determined very accurately. The influences on the work process of the pilot due to the crew concept are taken /18
into account by the task analysis, provided they include the work division, individual, prescribed activities or relations. Accounting for the different times for individual actions is possible by a Monte Carlo simulation in the calculation of the individual functions /35/. The basis of the analysis is of a normative nature where adherence to guidelines by the pilot and maintenance of specified time frames is postulated. The results of the analysis indicate whether these prerequisites are fulfilled. The reasons for exceeding the max. permissible workload are not made visible however.

Thus, chains of wrong actions of the pilot can lead to a suddenly occurring increase in demands and thus to pilot overload. Critical steps, decision-bearers or guidelines in the work organization which cause such danger situations are not recognized by an isolated consideration of time budgets.

In addition, the correct execution of the individual tasks is presumed in the analysis. Effects on the work process of the pilots resulting from an incorrect handling of individual tasks can also not be taken into account in the analysis.

As an aid in the description and calculation of the time profile of work processes, we have the waiting loop theory, in addition to the time-line analysis.

The fundamentals needed for analysis and calculation of the load on waiting loop systems are presented in /15, 19, 21, 33, 46/. Whereas an analytical solution is possible when considering simple systems, to obtain numerical solutions to complex systems, use of the Monte-Carlo simulation is suggested /33/. The basic procedure for simulation of waiting loop systems and program examples is explained in /46/. The equations for modeling and description of manipulation processes with the waiting loop theory are concentrated in the area of man-machine systems on monitoring tasks and man-machine cooperation.

The suggestion to describe the man-machine interaction by a waiting loop theory /31/ represents a relevant starting point of the evaluation method to be developed here. Proceeding from the modified requirements of men in modern systems of aircraft command, the modelling of man collaberating with intelligent /19 computers was evolved /8, 9, 32, 41/. The complex task-situation for man is reinforced by the example of the flight management task.

In /8/ the extent to which a variable task distribution (adapted to the workload on the pilot) can be achieved between the computer and pilot, is investigated to see how it will contribute to the performance of the entire system. The cooperation of man and computer was modelled by means of waiting loop theory and theory applicability was demonstrated for the flight management task /8, 41/.

The model is suggested for determination of the workload on pilots /8/. Compared to the results from the time-line analysis, the operating-theoretical view offers additional results through the possibility of flexible presentation of time-variant priorities in the operating process and by allowing an expansion to several operations /9/. Also, a calculation of the time workload on the pilot is possible not only as in the time-line analysis, but also an indirect determination of the workload via the length of the waiting loops /9/.

The results developed in the described work permit a definite conclusion about the applicability of the operating theory for modelling the cooperation of the pilots. Thus, for the evaluation method under development a theorem was suggested which puts the description of the work process in the cockpit into a waiting loop model with 2 operators (pilots) with parallel waiting loops. The tasks to be performed by the pilots appear as customers in the operating system. The theorem is described in sec. 3.1.

For a description of crew concepts, besides a description of the action sequence, the pilot decisions relevant to the work process must be taken into account. Any non-normative decisions should also be taken into account.

The theory of indefinite sets provides the possibility for presentation of imprecise statements with mathematic aids. Its fundamental definitions are presented in /51/.

The imprecise representation of verbal statements and the modification of evaluation criteria through additional subjective estimations are fundamental properties of human decision-making. Thus the Fuzzy Set Theory may describe and analyze human decision-making processes. Appropriate laws are presented in /3, 42, 50, 52/. They sometimes proceed from different structures for presentation of decision-making.

The equation presented in /50/ describes the decision- /20
making by means of a matrix of evaluation numbers. The matrix element B_{ij} $(0 \leqslant B_{ij} < 1)$ indicates the extent to which a possible alternative A_i fulfills a certain evaluation criterion C_j. Different-strength influences of criteria and relations of criteria to each other can be taken into account. The evaluation numbers B_{ij} are considered as imprecise companion values. The determination of the best alternative is done via a min-max determination in accord with the rules of the Fuzzy Set Theory.

The decisions to be made by the pilots shall be described in the computer simulation of the evaluation method to be developed for crew concepts. The structure of these decision-tasks is relatively specified by the alternatives and criteria described in the flight handbooks. An analysis corresponding to the theorem of /42/ by using decision-making trees would require measurement of all evaluation and probability functions, which practically could only be performed via pilot questionnaires which would lead to incorrect results. Therefore, for the analysis and description of the decision tasks we refer back to a form corresponding to that in /50/. The number of functions to be measured is reduced to the number of specified criteria. Whereas in the matrix only the specified and measurable criteria are taken into account, it seems useful to combine the subjective criteria of the pilot in the imprecise evaluation quantity B_{ij}.

The equation is presented in detail in sec. 3.2.

3.1 Waiting Loop Model to Simulate Action Sequences in the Cockpit

A waiting loop system was selected to describe the action sequences of pilots on the computer; it is illustrated in fig. 3.1. The system contains 2 parallel processing channels whose operators represent the two pilots in the cockpit. "Customers" or processing units of the system represent the tasks or activities to be performed by the pilots. In accord with the properties of these tasks, they are assigned into task classes and placed into a supply file. The supply file contains all possible actions of the pilots during the flight phase. The tasks appear in the crew system in accord with a specified time distribution; they are allocated to processing channels in accord with the work division of the pilots specified in the crew concept and are processed by the pilot or copilot.

If the pilot is busy with a task upon arrival of another task, a waiting loop forms. Once a task has been processed or an action performed, it leaves the crew system. Multiple-occurring tasks return to the supply file; final, completed tasks or one-time actions leave the cycle.

The effects of implementation of tasks on the flight command process and the processing status of tasks are determined in an information system and stored.

To determine the capability of the waiting loop system, we need to know the frequency and processing rate for the tasks to be handled. To apply the waiting loop model to the work process of a cockpit crew, the conditions of the flight command process have to be transferred to the functional mechanism of the waiting loop model. The parameters of the waiting loop system to be defined are assumed to be time-invariant within an operating phase.

In the definition of input parameters for the waiting loop system, functional and process-sequence parameters are differentiated (fig. 3.2). The function-specific parameters determine the allocation of tasks to the processing channels, the urgency of their processing and their time dependence on other tasks or events of the flight command process. These parameters can be found in the crew concepts and flight handbooks.

By the task-type, we mean the allocation of a task to a /22
processing channel in accord with the work division of the pilots specified in the crew concept. This takes into account that certain tasks can be performed by both crew members and assumes that the less busy pilot will perform the task. In this case, the lenght of the waiting loops is used as a measure for the workload on the pilots.

The task-dependence tells the causal sequence in which certain tasks can appear. It thus permits e.g. the entry of a task into the crew system only on the condition that other tasks have already been completed or certain system states have been reached.

The service discipline of the waiting loop system determines the sequence in which the appearing tasks are worked off. Three disciplines can be selected:
-first-come-first-served
-last-come-first-served
-absolute priority.

Thus it is possible to rank certain task priorities over other tasks, so that upon entry to the crew system, it will be worked off first.

Tasks with highest priority and special urgency are taken over by the pilot for execution immediately after their arrival, whereas the task being processed to this time is pushed back into the waiting loop.

The sequence-specific parameters represent characteristic quantities for the arrival and processing times of the tasks.

When using the model in a Monte-Carlo simulation, distribution functions (form and parameters) are to be specified for the arrival times and processing time of each task.

Furthermore, the definition of the maximum number of task arrivals in the operating phases is needed. If one-time arriving tasks cannot be clearly assigned to a certain operating phase, then their arrival probability must be taken into account in the individual operating phases.

With regard to the sequence of a flight command process, information is needed on the arrival times of individual events (e.g. timepoint of overflight of outer marker) and the duration of operating phases for consideration in the waiting loop system. The sequence-specific parameters were obtained from a measurement series run on a flight simulator. The determination of all parameters needed for simulation of crew activities on the computer is described in detail in sec. 4.

3.2 Simulation of Decision-Making Processes in the Cockpit /23

A rule was developed from the Fuzzy Set theory for simulation of decision-making processes in the cockpit. This rule is applied to the example of decision-making on continuance or termination of landing in terminal approach flight.

In this case the pilot's task is to identify visually the approached runway before reaching minimum height. If the runway is identified, the approach can be continued. If it is not visible, the pilots must decide to implement the wrong-approach procedure no later than after reaching the minimum altitude. The objective criteria for this decision are the visibility or identifiability of the runway and the altitude of the aircraft with respect to the minimum altitude.

The decision-making process can be illustrated in the form of a matrix as in fig. 3.3. The alternatives "land" or "go around" are evaluated with regard to the named criteria of "vision" and "altitude." The decision is made on the basis of a comparison of the evaluation numbers.

But since this is a decision-making human process, the evaluation factors are not measurable. In addition, it must be assumed that man will perform the evaluation of criteria based on a subjective estimation of the approach situation and will also use other, subjective criteria for his decision. The type and evaluation of such criteria likewise cannot be determined.

The structure in fig. 3.3 is taken as a basis for the simulation of decision-making tasks. The determination of the particular evaluation factors takes place under the presumption of evaluation functions which are also to contain the subjective criteria.

The presentation of such subjective evaluation functions takes place by means of the Fuzzy Set theory. The subjective evaluations are carried back to the objective and measurable criteria.

Fig. 3.4 shows e.g. the evaluation function for deciding between the alternatives "landing" based on the criterion "visibility." The qualitatively-indicated curve thus gives an evaluation number for each value of the visibility of the runway for the alternative "landing," which can be entered into the decision-making matrix (fig. 3.3). In this case, all subjective criteria and evaluations of the pilot are to be taken into account in the evaluation function. The corresponding evaluation function for the alternative "go around" based on the criterion "altitude" is also shown in fig. 3.4. After a determination of the factors for the matrix from the evaluation functions, the decision is made according to the rules of the Fuzzy-Set theory via a minimum-maximum calculation.

In order to be able to conduct the simulation of this decision on the computer, the corresponding evaluation functions must be known.

The evaluation functions should thus be determined from measurements on the flight simulator. From these tests the measured values for altitude and visibility of the runway-symbol and the results of the decision should be measurable. By means of the measured values, the evaluation functions can be formed.

Since the determination of the evaluation functions cannot be performed analytically from the results and input values of the decision-making matrix, the evaluation functions must be adapted to the test results.

The determination of evaluation functions will be explained in sec. 4.4.

4. Measurement Series on the Flight Simulator and Determination of a Data Base for Computer Simulation /25

The goal of the test series performed on the flight simulator is the determination of a data base for computer simulation of the activity sequence in the cockpit. The waiting loop model developed for the computer simulation (sec. 3.1) requires input data on the frequency and processing time of the individual tasks, and information on the arrival times of events which directly affect the activity sequence (e.g. reaching the outer marker or decision altitude, end of operating phases).

The decisions made by the cockpit crew which directly effect a change in the intended task plan of the pilots, are taken into account in the computer simulation using the example of the decision on landing or execution of the go-around procedure in terminal approach. The decision-making model developed here is based on the theory of indefinite sets and has been described in sec. 3.2. Decision-making of this model requires so-called evaluation functions which are to be determined from the test series on the flight simulator through measurement of the objective decision-making criteria and of the decision-result actually taken.

A 2-axis navigation trainer was available for the measurement series. The flight characteristics of the simulator correspond to those of a DC9. The cockpit equipment includes all navigation and the most important engine-monitoring instruments. With previously available equipment, the checklist work of the pilot was kept to a minimum. Therefore an overhead panel was suggested and built which permits an extensive checklist work for this test. In addition, the simulator was expanded to include a vision task for the pilot which was used to simulate the runway viewing in terminal approach.

An overview of the hardware expansions and measurement features of the simulator is given below (sec. 4.1). The description of flight tasks, test conditions and test sequence (sec. 4.2) is followed by a summary of measured results (sec. 4.3).

For application of the measured results in the computer simulation, a statistical evaluation of the measured data is needed; this is presented in sec. 4.4.

4.1 Expansions of the Flight Simulator and Measurement Facilities /26

The simulator was expanded to include an overhead panel in order to permit more extensive switching and monitoring tasks of the pilot in the tests. In the development of the panel, existing equipment in the DC9 aircraft was taken into account with regard to content and placement /14/.

The panel is shown in fig. 4 and the display and control elements are shown in fig. 4.2 and 4.3. Under consideration of the existing potentials with the simulator, only the functions summarized in group A can be simulated. Functions of group B sometimes affect the displays on the panel itself, whereas those in group C have no influence on the simulator.

The switching tasks provided in the tests and presented in the checklists can be performed by the elements presented in groups A and B.

To check the checklist work, monitoring of the timely and proper execution of these tasks is necessary. In order to do this, the overhead panel was expanded to include a monitoring logic unit.

In order to permit a pilot decision in the flight simulator on continuing the approach once the minimum altitude is reached, the runway visibility must be simulated.

Since no vision simulation was available for the flight simulator, a supplemental task of the pilot was designed which will still permit execution of this critical decision.

The task consists of the identification of a runway symbol having different brightness.

The symbol shows the approach lights of a runway as they appear to the pilot at about 300 feet altitude above the middle marker. The brightness of the symbol is controlled by the radio altitude finder of the simulator and can be overlapped by a noise signal.

The gradient of the brightness increase with decreasing altitude is adjustable on the instructor's console so that the symbol's visibility can be varied to simulate the influence of different weather conditions (see fig. 4.4, 4.5). In addition, different lights were installed in the vicinity of the symbol which light up in different configurations and brightnesses for each approach. Thus the task of runway identification is to be performed from the total picture seen. /27

The task is considered completed as soon as the pilots have made the decision on continuing or terminating the landing; the symbol is shut off and the final approach is continued by instruments on the simulator.

The measuring devices on the flight simulator should permit a determination of the time taken for all pilot actions, for action sequences, for radio communications and for system status. The procedure described in /36/ is taken as a basis for this.

Three multichannel printers and one tape recorder with 16 recording channels and 7 sound channels were available as recording instruments.

Besides the determination of the directly-measurable quantities on the flight simulator, the recordings of verbal exchanges of an observer is included; this observer sat behind the pilots and commented on their actions.

The structure of the measurement facilities is shown in fig. 4.6. For a chronological allocation of the data to the various data carriers, a time-pulse clock was built which places time marks or sound signals at desired clock frequency simultaneously on the printer and on the tape recorder.

The measured quantities transferred to the printer are all quantities of system status obtainable from the flight simulator. These are:

-course
-roll angle
-pitch angle
-elevators
-rudder deflections
-aileron
-barometric pressure /28
-radio altimeter
-indicated airspeed
-vertical velocity
-deviation from ILS glide path
-deviation from ILS Localizer course
-distance to landing point
-EPR setting
-flap position
-control unit for runway symbol brightness

The following information is transferred to the tape recorder:

-radio speech transmissions
-conversations between pilots
-commentary of the test director
-commentary of the observer
-other commentary
-time marks.

The recording of conversations between the pilots serves as a check of the prescribed communication guidelines, to determine non-relevant communication and to check the checklist read-off. The recording of commentary of the test director should contain additional information about system failures and special events as per the sequence of the test.

The use of an observer for the pilots became necessary in order to record all other pilot activities not directly measurable on the simulator or recordable on the tape recorder. Among these are e.g. the operation of the spoiler, selection of navigation and radio frequencies, setting the speed-bug or reading and writing of flight documents.

Other commentary was provided in order to record unforseen or unusual occurrances to the measuring equipment, settings and calibration of the equipment. /29

4.2 Test Conditions and Test Sequence

48 approach flights to 12 different German commercial airports were run. Each 4 flights were run under the same conditions on the same airport. The flight task for the pilots comprised the operating phases "initial approach," "holding/approach" and "final." The following designations and limitations were selected for the evaluation of the tests:

Phase 1: Initial approach — from beginning of test until Main aid is reached

Phase 2: Holding/approach — holding continues, intermediate approach until the approach baseline is reached

Phase 3: Final approach — until roll-out or initiation of the go-around procedure.

Both precision and non-precision approaches were used. The 12 different approach flights are listed in table 4.1 together with the pertinent weather and visibility conditions. Figure 4.7 shows the particular profile of one approach from this test series. In this form the information is presented on the flight task to the test director. Instructions on the radio speech contacts to be performed by him with the aircraft crew and information about special events to be simulated (e.g. failure of an engine or of navigation instruments) were also a part of this. The test plan also contained the data needed to set the weather and visibility conditions on the simulator and the radio speech frequencies valid for the approach.

The scope of the flight task is presented in fig. 4.7 for the example of an approach to the Hannover airport. The start of the test began with the aircraft positioned at radial 142 of Nienburg VOR in FL80 in the cruise flight configuration. The measurements began once the VOR Nienburg was passed. The flight task included the flight to VOR Hannover, execution of the holding procedure over the VOR and subsequent ILS approach to runway HNV 027R and possible execution of the go-around procedure. The task also included the execution of necessary procedure checks, of radio communications and management of flight documents.

The approach flights to the various airports were run in /30
alternating sequence so that the pilots had to adjust to new conditions for each test.

At the beginning of each test, the elevation and location of the aircraft, the flight status and the position of all control elements in the cockpit were initialized and frozen in. The pilots received their first information for the impending test as the TAKE OFF AND LANDING DATA SHEET with the needed information on the flight (fuel quantity, weight), destination airport and intended arrival route, and the aircraft location at the beginning of the test. Furthermore, the ground control center and frequency for radio speech contact were specified.

During the test the pilots had the following information available: ATIS, the needed ground control stations for radio contact and all navigation aids necessary for the approach. The instructions of the flight safety service and additional information for the test run specified in the test plan (fig. 4.7) are presented for all tests in table 4.2.

Two pilots were made available from Lufthansa; after 4 approach flights they exchanged roles as captain or first officer. The pilots flew in accord with the rules of the Crew Coordination Concept and all other instructions (procedures, minima etc.) of Lufthansa.

4.3 Measured Results /31

The results obtained from the test series run on the simulator should be used as input data for the computer simulation.

Initially, the starting and ending times of pilot activities and the arrival times of individual events were determined from the chart recordings. In order to do this, the pilot activities had to be defined, i.e. action units had to be specified.

The goal of the test series performed here is to obtain data for the development and fundamental demonstration of the operationality of the evaluation procedure. Therefore, at first a rough breakdown of pilot activities was selected which reduced the test or measuring effort and assured cohesiveness in the development of the computer simulation.

Thus, a summary of individual activities of the pilots into so-called tasks was performed. The characteristic values for the tasks were determined qualitatively only, due to the small scope of the measured series, but are held to be satisfactory for the named purpose. In particular the following definitions and conditions resulted for the measurements and evaluation of the test series:

Several activities of one or both pilots which served the same subgoal of the flight command task, were combined into one task; e.g. task "initiate descent" = shut off auto pilot
watch instruments
operate control horn
regulate descent rate
trimming (all for PF)

The tasks included in the test series and their pertinent activities are presented in table 4.3.

The processing and interarrival time (also called "between time") were determined for each task.

The interarrival time is defined as the time span which passes at the beginning of a task since the beginning of its previous processing, for its initial occurrance since the beginning of the test*.

---

*T.N.: This statement is totally unclear in the original.

Besides the task-specific quantities, the arrival time of events was determined, provided they relate directly to the pilot's task area. Among these are e.g. the arrival at the outer marker and the end of an operating phase. A total presentation of the obtained results is given in table 4.4. /32

The flights were divided into different operating phases for evaluation (see page 29). It must be assumed that due to the different requirements on the pilots in the different operating phases, different distributions of task-specific parameters like duration and between-time will result. The evaluation of the test series was thus separated according to operating phases.

Based on the selection of various airports and approach procedures, the individual approaches and corresponding operating phases exhibit large differences in duration. For once-only tasks and events whose between-time varied greatly over several flights as the difference from arrival time to test begin, the between-time was normed to the duration of the corresponding operating phase.

Based on the definition made on page 29, the "final" operating phase begins once the approach baseline is reached. The phase beginning thus varies greatly, depending on the specified approach procedure and according to the attained flight accuracy. Tasks and events in the "final" phase, like e.g. reaching the outer marker, reaching the decision altitude or the landing decision are specified very accurately through the specific conditions of the glide route, the altitude minima and the distances to the approach baseline. Their arrival times are thus not related to the phase beginning, but to the phase end. During the evaluation of the test series it turned out that once-only tasks (e.g. approach briefing or final check) could not be uniquely allocated to a specific operating phase under the prevailing definition of the operating phases (page 29). Since the given definition is retained for the computer simulation, the frequencies of the occurrance of these tasks were determined in the corresponding operating phases. The results are presented in table 4.5.

The test evaluation was initially performed by identification and marking of tasks and events based on the measured quantities in the recording and charts based on the synchronization marks. Next, the data input to the computer was done for further evaluation of test data (fig. 4.8).

After input of the allocation of synchronization marks in real time (program ZZ), the starting and end times of the individual tasks and event times were read-in (program DATEN). At the same time the DATEN program computed the time points in real time and the task duration and between-times were calculated. The expression shown in fig. 4.9 contains the measured and computed data from one approach according to test plan (fig. 4.7) for the "final" operating phase. With the HIST program finally, the histograms for the processing time and between-times of the individual tasks were computed per operating phase from the computed test data. /33

Using the same procedure with corresponding programs, the histograms were computed for the arrival time of the determined events (table 4.4). Table 4.6 gives an overview of the entire program packet prepared for the test series for data storage and test evaluation.

4.3.1 Adaptation of model Distribution Functions and Parameter Identification

After conclusion of the computations presented in the preceeding section, the histograms of the test data were available. For the histogram values H(i) we have:

$$H(i) = \frac{h(x_i)}{NGES}$$

with i = 1,100
x_i = measured value, x_1 = min. meas. value, x_{100}=max. value
NGES = number of measurements
$h(x_i)$ = frequency of occurrance of meas. values x with $x_i \leq x < x_{i+1}$

From the measured values the empirical average (mean)

$$\bar{x} = \frac{1}{NGES} \sum_{i=1}^{NGES} x_i$$

and the empirical variance were calculated as characteristic values of the measurement.

$$s^2 = \frac{1}{NGES-1} \sum_{i=1}^{NGES} (x_i - \bar{x})^2$$

In the Monte-Carlo simulation of crew activities on the computer, the values for the arrival and processing times of events or tasks were generated by the computer. The distribution function and its parameters desired for the values must be specified. If the computer-generated distribution of times of measurements should correspond to those on the flight simulator, then the adaptation of a model distribution function to the measured histogram must be performed. To simplify this computer generation it is expedient to use standardized distribution functions as model. /34

For the adaptations performed here, we were limited to a normal, exponential and Erlang-distribution.

The adaptation of a model distribution function to a measured random sample is only meaningful when measured and adapted function correspond to the same definition, relate to the same value-range and when they are visibly similar.

Therefore an adaptation to the histogram was performed through a model distribution density. Since the value range of the histogram is limited by the maximum and minimum measured value, the adaptation took place only within these limits.

The sometimes small number of measured values and the fixed distribution of 100 in the value range led in some cases to useless histogram images (fig. 4.10a). Thus the distribution was reduced, provided a greater histogram similarily to one of the named model distribution densities resulted (fig. 4.10b).

"Gaps" present in the histograms generated from the absence of measured values at individual points of the value range are filled by averaging the neighboring histogram values. Next, the histograms are normed again.

The changed histogram (for the purpose of a meaningful adaptation) is called the "measured distribution density" v(i) below.

Provided model functions are the normal distribution density: /35

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} \exp - \frac{(x-\mu)^2}{2\sigma^2}, \qquad -\infty < x < \infty$$

with the parameters μ, σ $\qquad \sigma > 0, \; -\infty < \mu < \infty$

the exponential distribution density

$$f(x) = \lambda \cdot e^{-\lambda x} \qquad 0 \leq x \leq \infty$$

with the parameter λ $\qquad \lambda > 0$

and the Erlang distribution density

$$f(x) = \frac{(k \cdot \lambda)^k}{(k-1)!} x^{k-1} \cdot e^{-k\lambda x} \qquad 0 < x < \infty$$

with the parameters λ, k $\qquad \lambda > 0$, $k > 0$, whole number

After selection of the type of form of the model, the parameter identification can begin.

In the literature /7, 46/ the instantaneous-method and the maximum likelihood method are proposed for estimation of the parameters of distribution functions. In this case the value range of the histogram is assumed to be unlimited ($-\infty < x \leq +\infty$). An adaptation of the distribution density within a limited value range is possible with the search-algorithm proposed in /34/.

We are dealing here with a method for seeking a local optimum of a multivariable quality function. When using the method on the problem at hand, the quadratic sum of the deviation of the model distribution density from the measured distribution density is selected as quality function:

Quality function

$$G = G(\hat{p}_1, \hat{p}_2) = \sum_{i=1}^{m} [v_i(x_i) - f(x_i, \hat{p}_1, \hat{p}_2)^2]$$

$$\longrightarrow \stackrel{!}{=} \text{MIN !}$$

To check the adaptation, the deviations of the average value, and of the variance of the adapted model distribution density from the empirical characteristic values of the histogram, are found.

The VANP program developed for the adaptation provides for /36
the conversion of the histogram into the "measured distribution density" after specification of the desired task, operating phase and reference quantity (between time or processing duration). The division of the value range can be changed as desired, in this case. After specification of the desired model distribution form and input of the start values, the adaptation occurs via the subroutine developed in /34/ when using the quality criterion from equation...

As start values we cite estimations for the parameters p_1 and p_2 of the model function and their probable changes. When performing the adaptation, the start values for the parameters are determined from the empirical characteristic values of the histogram determined as per the relations:

$\hat{p}_{1A} \approx \bar{x}$, $\hat{p}_{2A} \approx s^2$ for normal distribution

$\hat{p}_{1A} \approx \frac{1}{\lambda}$ for exponential distribution

$\hat{p}_{1A} \approx \frac{1}{\lambda}$, $\hat{p}_{2A} \approx$ depending on form; for Erlang distribution density

For a specification of the most likely changes in parameters, a value of ca. 10% of the parameter initial values is suggested in /34/.

Figure 4.11 shows the results of the adaptation using the example of the task duration of task 2 in phase 2.

In this case a reduced division was assumed for the conversion of the histogram (4.11) into the "measured distribution density" (4.11). Figure 4.11 also shows the distribution density resulting from the selection of the parameter-initial values and adapted finally by the search algorithm.

The results of the adaptation for the task-specific quantities, duration and between-time, are found in tables 4.7 to 4.9 separated according to operating phases. The determined statistical characteristic values for the phase lengths are shown in table 4.10; the adaptation results for the event-occurrance times are found in table 4.11.

Overall, all histograms could be adapted by the three preselected distribution functions. Through the sometimes very small scope of the measured values there resulted significant deviations of the mean for several functions and of the variance of the adapted function from the empirical mean and variance of the measurement. /37

As already mentioned, the qualitative determination of parameters and specification of a procedure for determination of the evaluation method is initially satisfactory.

For other tasks and more stringent requirements one would have to check whether the scope of measurements will meet the requirements. As a check of the adaptation, a significance test should be run. For checking the significance of adapted distribution functions, the Kolmorogov-Smirnov test is suggested in /6/ and /46/.

4.3.2 Determination of the Evaluation Functions for the Decision Model /38

For modelling of pilot decisions having a direct influence on the activity sequence in the cockpit, a fuzzy-set theoretical model was selected in sec. 3.2. The subjective decision-making of the pilot is simulated by means of a decision matrix (fig. 3.3). The application and testing of the model will be done here by using the example of making a decision on whether or not to terminate or continue the final approach once the minimum is reached. The alternatives of "land" and "go around" are assigned values in the decision matrix which relate to the objective criteria of visibility of the runway and of the present aircraft altitude compared to the minimum. The evaluations should contain all subjective factors affecting human judgement. The allocation of objective criteria like "visibility" and "altitude" to the subjective evaluation numbers is illustrated by indefinite-sets companion functions.

Simulation of the decison-making occurs through specification of the values for the aircraft altitude and runway visibility, followed by a search for subjective evaluations in the fuzzy-evaluation functions and determination of the decision result in the decision matrix by comparison of the evaluations as per the rules of indefinite set theory (fig. 4.12).

To implement the simulation the indefinite evaluation functions must be known. Their profile was determined from the test series run on the flight simulator.

As evaluation functions we found:

-HL (h) as companion function of measured values h for altitude to the total of all measured values which lead to a "land" decision,

-HG (h) as companion function of measured values h to the total of all measured values which lead to the decision "go around"

-SL (u) as companion function of measured values u to the total of all measured values which lead to the "land" decision,

-SG (u) as companion function of measured values u to the total of all measured values which lead to the "go around" decision.

The values of the companion functions thus express a measure of the potential for allocation of the present measured value h or u to the decision alternatives "land" or "go around."

For analysis of the decision-making conduct of the pilots in the test series, the measurement ranges for the altitude difference H ($H = H_{present} - H_{minimum}$) and the voltage U_s (control voltage for runway symbol) were broken down into intervals. In accord with the set-up of a histogram, the frequencies of the measured values u or h determined for the particular decision results, were determined for U_s and H.

Norming of the values took place together via HL and HL or SL and SG, respectively, by setting the maximum frequency of a measured value for U_s or H to 1.

The determined evaluation functions were taken as a basis for the EMOD program which performs decision-making upon input of two measured values for H and U_s as per the procedure illustrated in fig. 2.12. The obtained results however, have no similarity to the decision-making behavior of the pilot measured in the test series and partly contradicted the normative regulation for the landing decision.

Therefore, two additional assumptions were made which led to a modification of the evaluation functions:

Assumption 1: If the pilot at altitude h and visibility u decides to land, then he will make the same decision at the same visibility at greater altitudes;

or

If the pilot at altitude h and visibility u decides to go around, then he will make the same decision at the same visibility at lower altitudes for the flight approach procedure.

Assumption 2 is similar to the first one for measured quantity U_S: /40

The same decision of the pilot to "land" for the same altitude and better visibility (greater u)

or The same decision of the pilot to "go around" for the same altitude and worse visibility (smaller U).

The modification of the evaluation functions through the above assumptions corresponds to an integration of the evaluation functions. The first formation law for the evaluation functions (page..) was formulated analogous to that of a histogram. The assumptions change the formation law into an analogous law for a distribution function.

The determined evaluation functions were modified in accord with the additional assumptions and are presented in figures 4.13 and 4.14. Figure 4.15 shows the decision results obtained with the model compared to the parameters "visibility" and "altitude" in contrast to normative and simulator-measured decisions.

The model with modified evaluation functions gives results in full agreement with the results measured on the flight simulator (see fig. 4.15).

4.4 Determination of Parameters for the Function of the Activity Sequence in the Cockpit /41

For modelling the action sequences of the pilots, besides the time distribution and processing time of the individual tasks we must also know by which rules the tasks are distributed to the crew members and to what extent functional relationships exist between tasks and events in the flight sequence. Information on this topic was taken from the crew concept /1, 10, 45/ and flight operations handbooks /11, 14/. The parameters taken into account in the model are described below.

In the crew concept the work division and the functional principles of the activity sequence are specified. In addition, communication guidelines for the pilots specify the possibilities for delegation of tasks and responsibilities.

For the development of the evaluation method we first proceed from a normative behavior of the pilot so that the functional parameters for the model can be taken directly from the guidelines.

As the first parameter we determine the task distribution which tells for each task whether it is to be handled by CM1, CM2 or jointly.

The mission-specific conditions and the content of the individual tasks leads to material or chronological dependencies of the tasks and of tasks to events of the flight sequence. For example, the descent (task 2) can only be initiated when a release from flight safety has been received, or at least when a radio contact (task 25) has taken place. The final check shall be conducted as per operating handbook /11/ only after flying over the outer marker and is predicated upon a completed approach briefing.

Besides the parameters of the task and event dependence, the importance of every task and thus its priority over other tasks must be determined. Such priorities result e.g. due to time-indefinite events (radio calls to the FS) or due to the flight status (tasks of altitude, speed and position control). A distinction is made between tasks without priority, with normal and absolute priority. For normal priority of a task, it is /42
the next item handled directly by the pilot as soon as the pilot completes the activity already underway. For absolute priority of a task, the pilot interrupts his ongoing activity in order to complete the priority task at once.

Finally, from the specified mission profile for each task the frequency of its occurrence in the individual operating phases is determined.

A compilation of the determined parameters (task distribution, task dependencies, event dependencies, priority, max. frequency of occurrence) is presented in table 4.12.

5. Simulation of the Work Process on the Computer /43

In this chapter an overview is presented of the structure and potential uses of the computer simulation. With the planned application of the simulation program as an aid in the evaluation process for crew concepts, requirements are made of the simulation which are presented in sec. 5.1. With the overview and explanations of the program structure (sec. 5.2), the compilation of all input parameters is given for the computer simulation. Besides the parameters determined from the test series on the flight simulator, the characteristic values of the crew concept used in the evaluation-method development phase, are a part of this. In sec. 5.3 there follows the implementation and investigation of the computer simulation and a discussion of the possible simulation results, compared to the requirements presented in sec. 5.1.

5.1 Requirements of the Computer Simulation

The evaluation method for crew concepts designed here provides for a computer simulation of cockpit action sequences resulting from a certain work organization. Proceeding from a data base which contains the task and mission-specific characteristic values, a large number of flights will be simulated on the computer according to the evaluative crew concept and evaluated. The use of a Monte-Carlo simulation thus permits the evaluation of many different situations. At the same time, critical situations are to be recognized in the simulated action sequence and conclusions shall be drawn about regulations of the work organization which cause or promote said critical situations.

Different action sequences are formed in the computer simulation through variation of the task and event-specific parameters. The parameter variation is based on the limit values and distribution functions determined in chapter 2 for the parameters. The number of flights executed in the computer simulation should be /44 as large as possible so that the parameter distributions attained in the simulation come as close as possible to the specified distributions. The determination of a minimum number of simulation runs should be the first goal of the testing of this computer simulation.

Furthermore we must check to what extent the computer-simulated action sequences can be viewed as realistic or the same as the action sequences actually observed on the flight simulator. Conclusions in this regard should give the arrival, processing, system and waiting times for the tasks in the computer simulation.

The goal of the evaluation process is to determine critical events in the action sequence of the pilot. Critical events are those temporal task pile-ups which indicate pilot overload. The consequence of pilot overload can also be that certain tasks cannot be completed within a specified timeframe. Such events should also be recognized in the computer simulation.

Besides the recognition of critical situations, the tracking of the simulated action sequence in reverse order must be possible in order to draw conclusions from the actual event about its causes.

5.2 Program Overview /45

The program packet for simulation of the action sequences and evaluation of the work organization is presented in the overview, table 5.1. It is broken down into sections on "parameter input," "simulation" and "statistical evaluation."

The parameters determined in chapter 4 or the characteristic values of their distribution functions are read in by the programs CINI and CEIN and are stored on magnetic disc for the simulation. We are dealing with the between-times, processing times, task allocations etc. In table 5.2 there is a listing and explanation of all input values. The input and storage occurs, like the simulation, in accord with the results obtained in chapter 4, separately by operating phases.

For the simulation of action sequences the main program CREW was developed; it has the subprograms listed in table 5.1. In the main program we have the read-in of parameters from the magnetic disc, the selection of operating mode of the simulation and the specification of mission-specific events.

The main operating mode is the simulation of max. 100 approach flights with simultaneous data storage for the evaluation with an overview printout. The storage of internal variables of state at the beginning and end of each simulated approach permits a continuation of the computer simulation in future program runs and also, in the second operating mode, any approach flight of the last program run can be reconstructed and printed out in detail down to each individual result of the action sequence.

The mission-specific parameters (phase duration, timing of arrival at outer marker or decision minimum, runway visibility, timing of other events) can be read-in as fixed values or varied according to specified distributions.

5.2.1 Simulation Program /46

The simulation by means of the waiting-loop model selected in chapter 3 occurs in the subprograms
CREW, CQS, STATUA, STATUQ, STATUS, UARR, USER, RANDUX, INF, AUS and EMOD.

The principle of the waiting-loop simulation is illustrated in fig. 5.1 and was taken from the descriptions in /46/. It is assumed that the system is empty at the beginning of the simulation. After determination of the next arrival time of a task, the next event is determined through a comparison of the timing of the possible events. The simulation jumps ahead in time to this timepoint.

Possible events are:
-the occurrance of a task in the crew system
-the completion of a task in channel 1
-the completion of a task in channel 2
-the end of the simulation
-the completion of a joint task in both channels
-the end of the simulation

Upon arrival and completion of tasks, the quantities of state of the crew system are changed for the affected channels, in addition to a change in corresponding timepoints. These quantities of state are:

-number of tasks in channel 1
-number of tasks in loop 1
-number of tasks in channel 2
-number of tasks in loop 2
-number of tasks in the entire system.

Since for the discussion of the crew system, not only is the number of tasks important, but also which particular tasks are in the system already, as an additional quantity of state we added the "status" of a task. The identifying numbers appended to this quantity have the following meaning:

STATUS (task X)	= 0	Task is in the supply file
	= 1	Task is in loop 1
	= 2	" " " " 2
	= 3	" is being processed in channel 1

= 4 Task is being processed in channel 2
= 5 Task completed and is no longer in the system nor in the supply file
= 6 Task in channel 1 or 2 was being completed, but was kicked back into the waiting loop by a priority task
= 6.8 Corresponds to STATUS=6, for tasks which have to be completed jointly by CM1 and CM2.
= 7 Task in loop 1 and 2 to be completed jointly
= 8 Task in loop 1 and 2 is being completed jointly

For the positioning or sequence of tasks in the two waiting loops, a quantity of state was also defined.

Thus it is possible on the one hand to represent at any time of an event in the waiting loop system, the positions of all tasks present in the system. On the other hand, the status of all tasks, regardless of their position within or outside the system, can be represented.

Tasks can be simulated which have to be completed by CM1 and CM2 individually or simultaneously.

The beginning of processing of such tasks becomes possible once CM1 and CM2 are not busy.

The simulation of the "absolute priority" of a task provides that the task presently being handled by the corresponding crew member, is set back into the waiting loop upon arrival of the task with absolute priority. The priority task is handled immediately. If the reset task is to be handled by both pilots jointly, it is only set back into the processing channel in which the priority task appears. The other crew member handles the "joint" task in the meantime (fig. 5.2). /48

For the generation of between-times and processing times of tasks, the exponential, Erlang and normal distributions are available as distribution forms. The values for the between-times and processing times were generated within the input limits in accord with the selected distribution.

The program packet for simulation of the crew system is of modular design (see fig. 5.3). The core of the program packet is the new CQS program which specifies the time sequence of events in the crew system according to the principle shown in fig. 5.2 and described above. All data of state is read at the beginning of the simulation from disc memory or is transferred to disc memory after the end of the simulation. Thus the simulation of a longer flight task can be broken down into small time intervals in which the number of possible activities and tasks remains constant or becomes smaller.

Input values for the simulation are: Characteristic values for pilot tasks, type and duration of the desired operating phase, characteristic values for the arrival times of individual events (e.g. time of overflight of outer marker etc.).

Whereas the CWS program will determine only the time sequence of events and the quantitative quantities of state (length of waiting loops, number of tasks in the system), the subprograms take over the positioning of the tasks within the system, the determination of values for the timepoints of events and the determination of the effects of activities.

The subprogram UARR determines for each task, in accord with the specified distribution function, the timing of its next occurrence in the crew system. By seeking the minimum of these time values, the timing of the next following task arrival and the task itself are determined.

If the CQS program determines the next event to be the arrival of a task, then the STATUA program takes over the positioning of this task in the waiting-loop system. The classification in the processing channels as per the specified task division of the pilots is governed by the input of the variable "task type" (AT). The ordering of tasks in the waiting loops is governed by the specified service discipline mentioned in sec. 4.1 (variable DISZ). /49

Before the task at the front of the loop can be taken over by the "pilot" for processing, the STATUQ program (fig. 26, 27) checks whether all prerequisites with regard to system status or other tasks have been fulfilled.

In order to do this, the variables "task dependence" (AAZ) and "status dependence" (ZAZ) were introduced. If the task still cannot be processed, it is set to the end of the loop and the program moves all following tasks in the loop up by one place.

The STATUS program (fig. 28, 29) finally, has the task of specifying the effects of pilot activities in the information file, provided they affect the following activity sequence; it must also calculate the new status of the tasks.

The processing time for tasks is determined as per a preset time distribution in the USER program.

Pilot overload due to the quantity of tasks to be executed is determined in the waiting-loop model on the basis of two criteria:

If very many tasks are to be completed by the pilots in a certain time span, then a pile-up of tasks in the waiting loop is expected. The waiting loop is additionally filled because tasks arrive which cannot yet be processed due to their dependence on other tasks or events, or because they are set back by priority tasks. Thus the waiting time for a task in the loop can get so long that the task is not completed at a time in the flight when it is to have been completed according to the flight operations handbook. Thus, pilot or crew overload occurs such that the specified tasks cannot be completed within the given timeframe.

The subprogram KRIT performs a search for such overload-occurrences in the computer simulation.

The second criterion for pilot overload is the simultaneous existence of the same task in the same processing channel of the model. For instance, tasks occurring at high frequency can stack up in the waiting loop if they are worked off only at a much slower rate. In this case a pilot overload is recognized by the simulation program when the number of units of the same task present in the system exceeds a limit specified in the main program (NUBL). The level of this limit is 'a priori' impossible to specify in a plausible manner and will be determined during the computer simulation. /50

The model developed in chapter 3 for pilot decision-making on continuation of the terminal approach is verified in the computer simulation of crew activities in the EMOD subprogram. In the computer simulation the landing decision is split into two stages which are handled as separate, but mutually dependent tasks (fig. 5.4).

The first step is represented by task 11 (field in sight). It is processed by CM2 and represents the view of the copilot and identification of the runway. After computation of the present aircraft altitude from the time of task processing (calculation of the time span to set-down and assumption of an average descent rate of 700 ft/min) and specification of "visibility", the result is determined by the decision-making model developed in chapter 3. The decision is interpreted in the first stage by the statement "Field in sight" (for "land" decision) and as "no report" (neutral for "go around"). The arrival times of task 11 were determined from the arrival times of the call-out "field in sight" (chapter 4). The second stage of decision-making is represented by the task 12 "landing decision." It is handled by CM1 and is dependent on task 11. If in step one "field in sight" is noted, then the result in the second step is "land." If task 11 is the neutral result, then in task 12 after calculation of altitude and visibility, the decision model is applied again. The determined decision is now interpreted directly as a "land" or "go around."

5.2.2 Evaluation Programs /51

The evaluation of the computer simulation takes place by means of the SIHIST program (table 5.1). For each task the histograms, average values and variance of the following quantities are determined:

-arrival time/or between-time
-beginning of processing
-end of processing
-waiting time
-duration of processing
-time remaining

The "time remaining" is the processing time of tasks which is left over at the end of the operating phase which could then be applied to the following operating phase.

Furthermore, we determined:

-duration of operating phases (desired value)
-actual duration of the simulated operating phases
-workload on CM1
-workload on CM2
-frequency of overloads keyed by causes.

The actual duration of the simulated operating phases deviates from the desired value due to termination of the simulation once the pilot is overloaded.

The workload on the pilots is defined as the ratio of the busy time to free time in percent.

As a result of the computer simulation, the histograms of the number of values, linear average and variance were determined for the following quantities: /52

a) Arrival time, beginning of processing, end of processing (for once-only tasks)
b) Between-time (for repeat tasks)
c) Waiting time, processing time and remaining time (for all tasks).

Furthermore, the frequencies of crew overloads, keyed by causal tasks, were determined. To reconstruct the causes of the overloads, individual simulated approach flights can be repeated and printed out in detail.

5.3 Results of the Computer Simulation /53

The program packet for simulation of the pilot's work sequence described in the preceeding sections was checked first for operating phase 1 on the computer (initial approach).

The input parameters relevant to operating phase 1 are shown in table 5.3.

Based on the detailed printouts (see fig. 5.5) for various approaches, the correct function of the waiting-loop model was checked and validated in accord with the function principles described in sec. 5.2. Next, test series 1, operating phase 1, was implemented with 2000 approach flights.

The operating time per phase was set to PHL = 235.5 here (average of phase duration measured on flight simulator).

As overload criterion we selected NUBL = 3 task units (see sec. 5.2).

To determine the minimum number of flights to be performed in the computer simulation, a pre-investigation was performed. By using the USER and UARR program modules (generators for arrival and operating times), the deviations from the mean of simulated arrival and processing time-distributions from a desired value were determined. The results are presented in figures 5.6 and 5.7. For all tasks there results a deviation of less than 5% from the mean for 500 values per measured quantity. This minimum number of measured values can be reached with 1000 simulated flights, given the constantly recurring tasks in the computer simulation.

The events of the computer simulation are presented in tables 5.4 and 5.5.

A comparison of the numbers of arrival time and beginning of processing shows that in 368 of 430 cases, the processing of task 4 does not begin in operating phase 1.

The ratio of 62 actions in phase 1 to 368 actions in phase /54
2 lies far below the specified probability of task frequency of task 4 of 28% in phase 1 or 72% in phase 2, respectively. An explanation here using the average, long waiting times, is possible. The "arrival times" of tasks measured on the simulator are simultaneously the beginning times of their processing. In the waiting-loop simulation, these two timepoints are not identical in the model. The resulting systematic error had not heretofore been taken into account in the method.

The results of the computer simulation for task 4 are documented in fig. 5.8. In a comparison of arrival times, beginning of processing and end of processing, the waiting and processing times are discernable even in an overview. The delayed arrival of the task in the timeframe of the operating phase leads to a small number of measured values for the operating duration (together with the relatively long waiting times; small number of task completions within the operating phase) and to a large number of overlaps in phase 2 (time remaining).

The crew overload events reported by the computer simulation are sometimes caused by the simulation program itself. For instance, we referred above to the large number of overloads due to task 4 (descent check) which can be attributed to a methodological error not taken into account in the method. The overload due to an increased number of tasks 8 and 13 in the waiting loop (NUBL $>$3) can also be attributed to the method.

The processing discipline of task 8 (radio communications) could be reduced to DISZ=2. Thus, an immediate reaction of the pilots to radio inquiries would be simulated. For the processing descipline for task 13 (communication), a similar solution would be possible. However, a distinction would have to be made between additional (redundant) and action-related or time or event-dependent communication.

Such a distinction presumes a variation of the DISZ parameter in the simulation program during the test series which could only be achieved with considerable programming effort.

6. Summary and Outlook /55

An optimum structuring of man-machine systems using analytical means requires an analytical description of human modes of action. In the case of flight management, this includes not only a consideration of the man-machine cooperation, but also a description of cooperation among the cockpit crew.

As already explained in the problem section, the previous, empirical development of crew concepts is not sufficient for regulating the pilot's work organization, to prevent incorrect pilot actions with resulting flight accidents. In addition, modern technologies will cause a change in the work structure in future aircraft cockpits.

The goal of the research project was to develop a system-theoretical procedure which could be used for cockpit-crew work-process structuring to check a selected work organization. The method should ensure a high-level of cooperation among the pilots and it should take into account the fact that the pilots under some circumstances will not behave in accord with specified procedures.

The procedure for development of this evaluation method initially provides for a description of the actions and decision-making processes in the cockpit by a computer simulation taking into account the work organization under study. The development of the method is limited to a discussion of a representative work organization and flight tasks. After validation of the descriptive forms, the crew performance of the computer simulation was made available to an evaluation method.

In chapter 2, we first presented the parameters which affect the cooperation of pilots and the crew's capability. This was compared to the primary structures and guidelines of existing crew concepts. From this comparison we worked out the requirements of the developmental evaluation method and finally designed a procedure for development of the method.

The factors affecting the crew performance named in section 2.1 are: The number, composition, cooperation and organization of the pilots. Improvement of crew capabilities through individual cooperation and grouping of pilots is not possible in large airline companies. /56 The potentials of aircraft owners to affect the cooperation of their pilots is thus limited to a specification of the number, work organization and communication of crew members.

Whereas the number of crew members depends primarily on the particular task profile and the resulting crew workload, a balanced workload on the individual crew members should be achieved through a selected work organization with a specification of cockpit work division. The flexibility of the pilots in the performance of their tasks should be adapted to the particular situations and work methods. The flexible structuring and coordination of cockpit activities requires the specification of communication guidelines in order to assure a precise transmittal of information, instructions and pertinent responsibility for actions.

From the structures of existing crew concepts examined in sec. 2.2 it follows that the possibilities for affecting crew jobs are basically exhausted.

A closed, systematic theorem for general work organization in the cockpit has only been given in one case. But for the capability and safety of the cockpit crew, the performance regulations derived from the general guidelines are critical.

For example, from the preceeding discussion it can be concluded that a division of activities or responsibilities and the resultant interactive decision-making processes might lead to conflict situations between crew members.

Covering such conflict situations and the consequences on the flight command process and pilot work processes should be one of the goals of the developmental evaluation procedure. The method should also determine critical decisions and decision-makers as well as a time distribution of the workload of the individual crew members.

From the preselection of theories and descriptive forms for the evaluation process (chapter 3) the waiting-loop theory, fuzzy set theory, iteration matrix and time-line analyses were determined to broaden the investigation. The time-line analysis is already used for the empirical development and evaluation of crew concepts. Its task analysis for determination of individual crew activities should also be applied to the evaluation method under development here. /57

By using the waiting-loop theory, information on the structuring of similar tasks has already been developed.

The use of the waiting-loop theory for a flight management task for describing the man-computer cooperation yielded results which indicate the theory's validity for the evaluation method.

The possibilities for describing the decision-making process in the cockpit are limited by the vague process of human decision-making influenced by subjective criteria.

The estimation of the influences of criteria or of decision-makers on a complex decision-making process can be described by using iteration matrices, but if the decision criteria are not known completely--as is the case for human decision-making--then other descriptive forms will have to be used. Under consideration of the imprecise human criteria for judgement, his subjective estimations or verbal statements, the fuzzy set theory offers a possibility for describing the decision-making process.

The characteristics of crew activities discussed in chapter 2 and the descriptive forms examined in chapter 3 led to the development of the theorem presented in sec. 3.1 and 3.2 for describing the action sequences and decision-making processes in the cockpit.

The handling of tasks and activities in a 2-man cockpit was simulated by a 2-channel waiting-loop system. The computer programs already developed to describe the action sequence are presented in chapter 5.

Cockpit decision-making processes are simulated by indefinite evaluation functions which refer back to measurable decision-making criteria and which should take into account all subjective influences on decision-making.

The investigation of the operating theorem in a Monte-Carlo simulation required statistical data on the individual actions to be illustrated with regard to their frequency and processing times; this was obtained by measurements on a flight simulator. /58

Analysis of the flight simulator data with regard to pilot decision-making was performed to determine the indefinite evaluation functions.

Implementation of the tests on the flight simulator and in particular the extensive measurement instrumentation are described in sec. 4.1. We are dealing with the development of an overhead panel for the flight simulator which will permit a real execution and simultaneous monitoring of switching tasks and checklist work of the pilots. Furthermore, a visual task was conceived which allows the pilots in the flight simulator to make the critical decision of termination or continuation of the landing procedure in terminal approach flight.

The test series on the flight simulator was made up of 48 approaches to 12 different German commercial airports (sec. 4.2). The weather and visibility conditions were varied, the test persons (2 pilots from Lufthansa) operated according to the rules of the crew Coordination Concept and other operating instructions of Lufthansa. For the evaluation, the approaches were divided into operating phases: "Initial Approach," "Holding/Approach" and "Final."

For each pilot task, the arrival times and processing times were measured. In addition, the arrival times of individual events important for pilot action sequences were determined.

The evaluation of the test series was composed of the determination of characteristic values for the time profile of crew tasks (sec. 4.3), the determination of characteristic functions for the pilot's decision-making behavior (sec. 4.4), and the determination of functional relations of pilot tasks (sec. 4.5). The basis for the measurement of characteristic values of the action sequence was the definition of action units for which the parameters were to be determined. Based on the application of data for development of an evaluation method or computer simulation, the smallest possible, cohesive quantity of action units was viewed as expedient. Therefore, the individual actions of the pilots were combined into action groups, called tasks here.

From the measurements on the flight simulator histograms were prepared for the processing time and the between-time (inter-arrival times) of the tasks (sec. 4.3). Furthermore, the histograms of arrival times of events of the flight sequence were determined as they related directly to the activity sequence in the cockpit.

The task-specific parameters were determined separately by operating phases. Different-length operating phases on the flight simulator were taken into account by norming the arrival times to the phase duration.

The determination of measured values took place through manual evaluation of the measurement protocol of flight simulator with subsequent input to the computer.

For the input and processing of measured data a program-packet adapted to the needs of the test was produced.

The determined histograms were adapted by model distribution densities. Based on the sometimes small number of measured values, modifications of the histograms were needed with regard to the division and norming, in order to allow comparison with the model distribution densities according to definition. The adaptation was done on the computer by using a search algorithm with a specified quadratic quality criterion. Models used were: the normal, exponential and Erlang-distribution densities.

The characteristic values determined from the adaptation (shape and parameters of the distribution, average value and variance) are not significant for all tasks or measured quantities. Within the framework of the development of the evaluation procedure for crew concepts, a qualitative estimation of the parameters was sufficient, however. Pilot decisions having a direct influence on the action sequence in the cockpit were examined using the example of decision-making on continuation or termination of landing in terminal approach flight.

For modelling the decision-making with a fuzzy set algorithm, evaluation functions (fuzzy companion functions) were needed for the individual alternatives of the decision-process.

Determination of these subjective evaluations for the alternatives "landing" or "go around" took place through measurement of the objective criteria "visibility" and "altitude" and the corresponding decision of the pilot (sec. 4.4).

Formation of the evaluation functions via the frequency of decision-results for specific visibility and altitude values led to a decision-model which correctly simulated in part the decisions measured on the flight simulator. This can also be attributed to a very small data base. The evaluation functions were therefore modified by additional assumptions which extrapolated the decision-behavior of the pilots from measured values to comparable situations. /60

With the resulting decision model, a complete agreement with decisions measured on the flight simulator was achieved. Besides the characteristic values for the chronological action sequence and the evaluation functions for the decision model, we also need parameters--in order to simulate crew activities on the computer--which describe the functional task-sequence in the waiting-loop model (sec. 4.5). We are dealing here with the allocation of tasks to the pilots, their time and functional dependencies on events of the flight sequence, or on other tasks, and with task priorities. These parameters were determined from the flight handbooks and were specified for the individual tasks according to the operating phase.

As the basis for the crew-concept evaluation method, a Fortran program was prepared for simulation of the activity profile. The program is based on the descriptive forms selected in chapter 3.

The following program requirements were taken into account in developing the program packet into a working part of the evaluation method (sec. 5.1):

The reason for the computer simulation is to investigate the greatest-possible number of different situations and action sequences. Variation of the parameters should correspond to real conditions as much as possible.

Critical situations which indicate pilot overload should be recognized. Critical situations are defined as a pile-up of units of the same task in the waiting loop. Moreover, it is a critical situation when a task is not completed within the alloted timeframe.

In the case where such overloads occur, the computer simulation should allow a reconstruction of the corresponding action sequences to permit discovery of the reasons for the overload. /61

The developed simulation program (sec. 5.2) provides for the simulation of 100 approach flights in one program run with subsequent statistical evaluation. Based on an overview printout, flights containing critical situations can be discovered. If necessary, a repeat of the simulation of selected flights is possible, with a detailed printout of all changes of status in the waiting-loop model.

By storing the internal status data of the model after each program run, the simulation of action sequences can be supplemented by an additional 100 approach flights. The data of the statistical evaluation is accumulated accordingly.

The first test series run with computer simulation (sec. 5.3) was performed for the "Initial Approach" operating phase and had the following objectives:

- An estimation of the minimum number of needed simulated flights was to be discovered from a comparison of the specified distributions of the task-parameters with the distributions resulting from the Monte-Carlo simulation.
- Based on detailed printouts for the changes in status in the waiting-loop model, a check was run on whether the simulated action sequences correspond to real (normative) principles of crew cooperation.

The results after simulation of 2000 approach flights using random sampling, confirm the correct, normative or plausible functional operation of the waiting-loop simulation.

In a statistical evaluation of the task-specific parameters a sufficient agreement of the specified distributions was found with the distributions of the simulated values. A fixed run with the appropriate program modules showed that the average values of the arrival and processing times of all tasks have an error of less than 5% after about 1000 simulated values.

In the test series on the flight simulator the timepoints of beginning the activity and the duration of the activity were measured for the individual tasks. For the waiting-loop simulation, the parameters determined for the beginning of activity were used for the arrival times of tasks in the waiting-loop system. This allocation was selected since a unique arrival time cannot be measured or specified for all tasks measured on the simulator. /62

In the evaluation of the first simulation series it turned out that this allocation causes a significant, systematic error. Since in the waiting-loop simulation sometimes considerable waiting times for tasks result, the task processing is shifted far toward the end of the operating phase or even beyond it. From this result overload messages from the program and a change in specified processing probability for individual tasks for the operating phases which do not correspond to the circumstances measured on the simulator.

With the program packet for simulation and evaluation of the action sequence in the cockpit, the applicability of the waiting loop simulation as an integral part of the structuring process for crew concepts could now be determined. To validate the entire process, its application to a real crew concept had to be performed with a complete set of tasks or activities.

The expected large programming effort for these interactions or temporal and functional dependencies of many single actions could be counteracted by the use of another programming language (like e.g. SAINT). Compared to other methods of development or testing the work sequence in the cockpit, with the waiting-loop simulation, functional relationships of work-organization rules and their effects on safety and performance of the crew can be evaluated in any large number of situations. Thus, a meaningful use of the method in structuring the work processes of cockpit crews can be anticipated.

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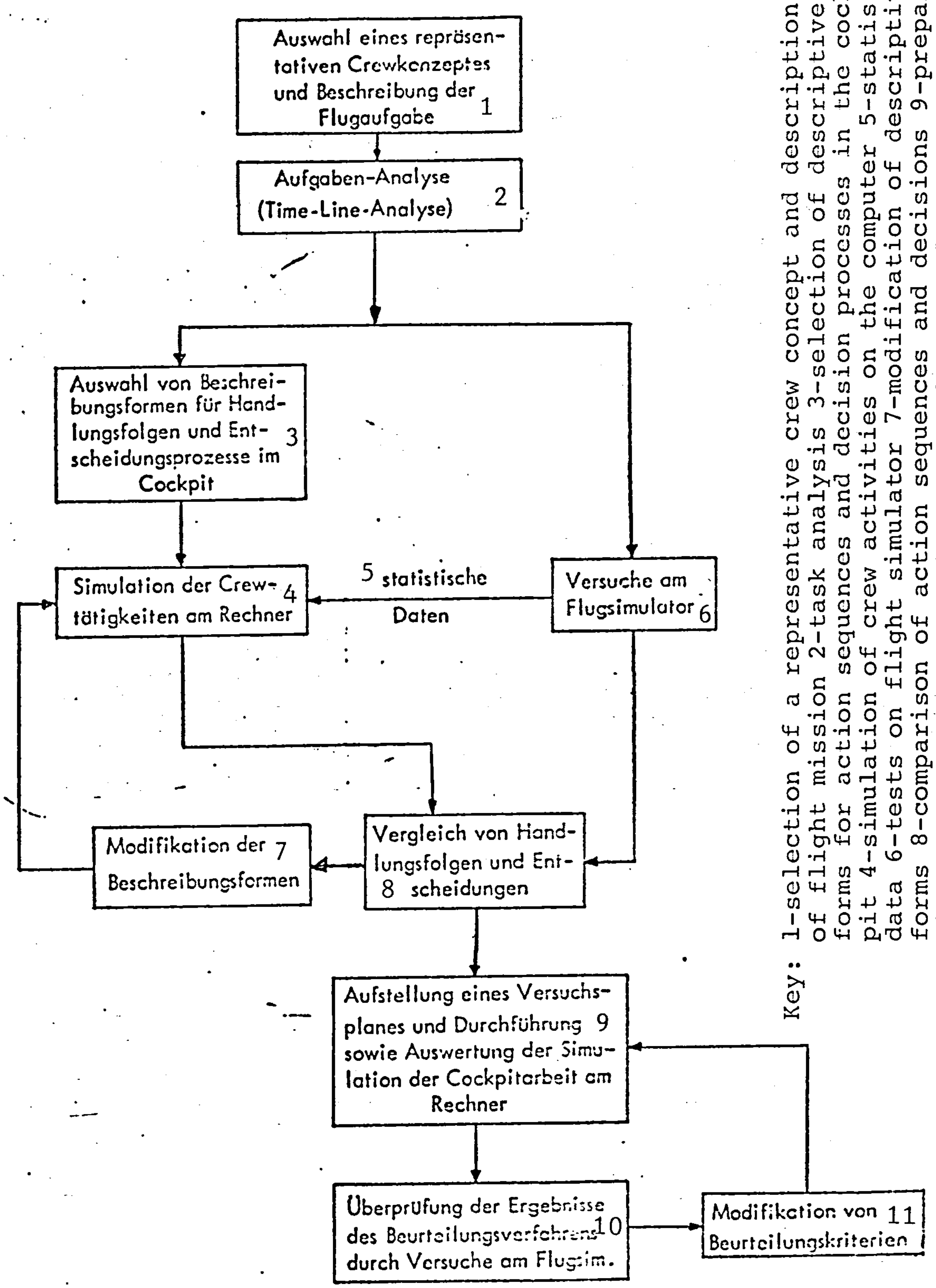


Key: 1-selection of a representative crew concept and description of flight mission 2-task analysis 3-selection of descriptive forms for action sequences and decision processes in the cockpit 4-simulation of crew activities on the computer 5-statistical data 6-tests on flight simulator 7-modification of descriptive forms 8-comparison of action sequences and decisions 9-preparation of a test plan and implementation & eval. of computer simulation of cockpit work 10-check of results of the evaluation method by tests on flight simulator 11-modification of evaluation criteria

Fig. 1: Procedure for the Development of an Evaluation Method for Crew Concepts

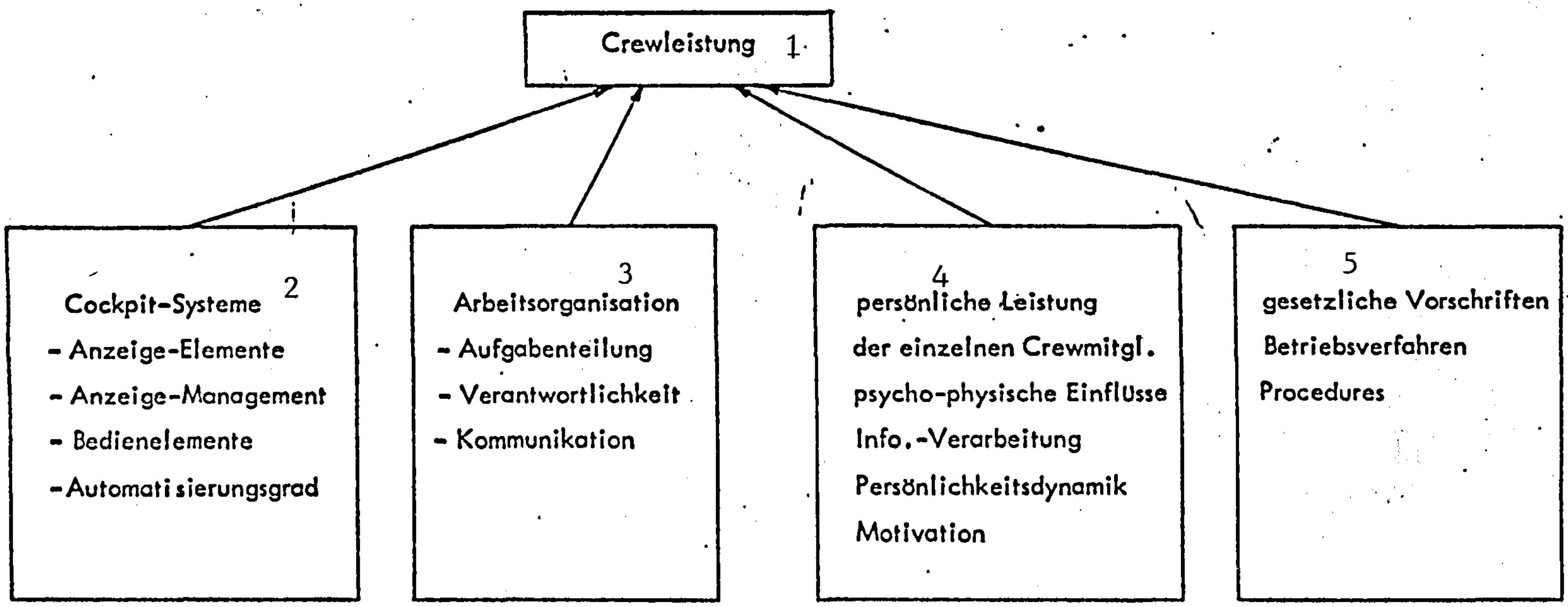


Fig. 2.1: Influences on the Capability of the Cockpit Crew

Key: 1-crew performance 2-cockpit systems; display elements; display management; control elements; level or automation 3-work organization; task division; responsibility; communication 4-personal performance of individual crew members, psycho-physical factors; infor. processing; personality dynamics; motivation 5-legal specifications; operating methods; procedures

PF	PNF
Control of the aircraft	Support and monitoring of the PF
Tracking specified flight procedures	Radio communications
Maintenance of flight safety	Setting, identification and checking of navigational aids according to the instructions of the PF
Altitude and speec limitations	
Observation of airspace	Management of necessary flight documentation
Preparation of aircraft for the individual phases of the flight, and correct useage of checklists	

Fig. 2.2: Basic Task Distribution of the Pilots /10/.

	PF	PNF	BOTH
Manual	Checklists (execute) Control of aircraft Altitude & speed limitations Setting of approach beacon and landing aids	Checklists (read) Radio communications Set thrust and flaps Monitor engine instruments Raise and lower landing gear	Maintain flight safety approval Manage needed flight documents
Auto. Pilot (AP)	Monitor thrust & speed	Monitor rate of descent Monitor & change frequencies for radio communications Monitor PF instruments Monitor approach beacon & landing aids Set thrust	Select & check frequencies Set altimiter
Flight Director (FD)	Flight control and monitoring of instruments	Select flight director Modes Test FD displays Monitor PF actions Select speed & mon. ASI Monitor correct flight path	

Fig. 2.3: Basic Task Distribution for the Pilots from /6/

Tätigkeit 1 \ Crew-Member	ATLAS-GRUPPE						US-CARRIER		IPIS	
	CM1	CM2	CM1	CM2	CM1	CM2	CM1	CM2	CM1	CM2
Rolle 2	PF	PNF	PNF	PF	PNF	PF	PF*	PNF	HDP	HUP
Anflug nach Instrumenten 3	x			x		x	x		x	
Höhen ablesen u. Callouts 4		x	x			x		x	x	
Aufsuchen des Sichtkontaktes zur RWY 5		x	x		x			x		x
Meldung über F.I.S. oder DH/MDA 6		x	x		x			x		x
Landeentscheidung 7	x		x		x		x			x
Rolle 2	PF	PNF	PNF	PF	PF	PNF	PF	PNF	HDP	HUP
Fortsetzung des Anfluges nach Sicht 8	x			x	x		x			x
Kategorie 9	1		2		3		1		4	

Fig. 2.4: Different Potential Applications of Crew Concepts with the Same Role Division (for terminal approach)

Key: 1-activity 2-role 3-approach by instruments 4-read off altitude and call-outs 5-seek visual contact with runway 6-report F.I.S. or DH/MDA 7-landing decision 8-continue visual approach 9-category

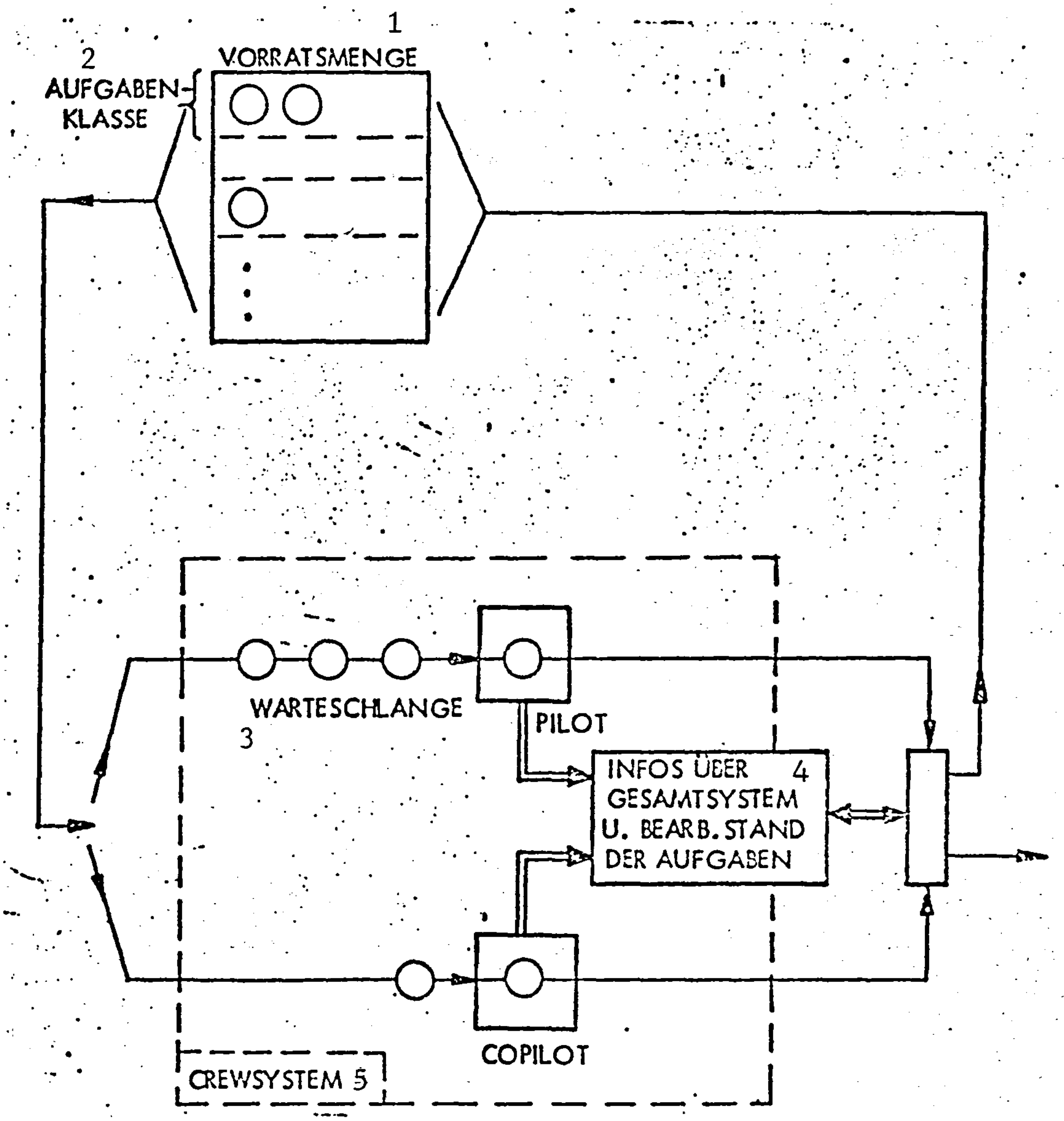


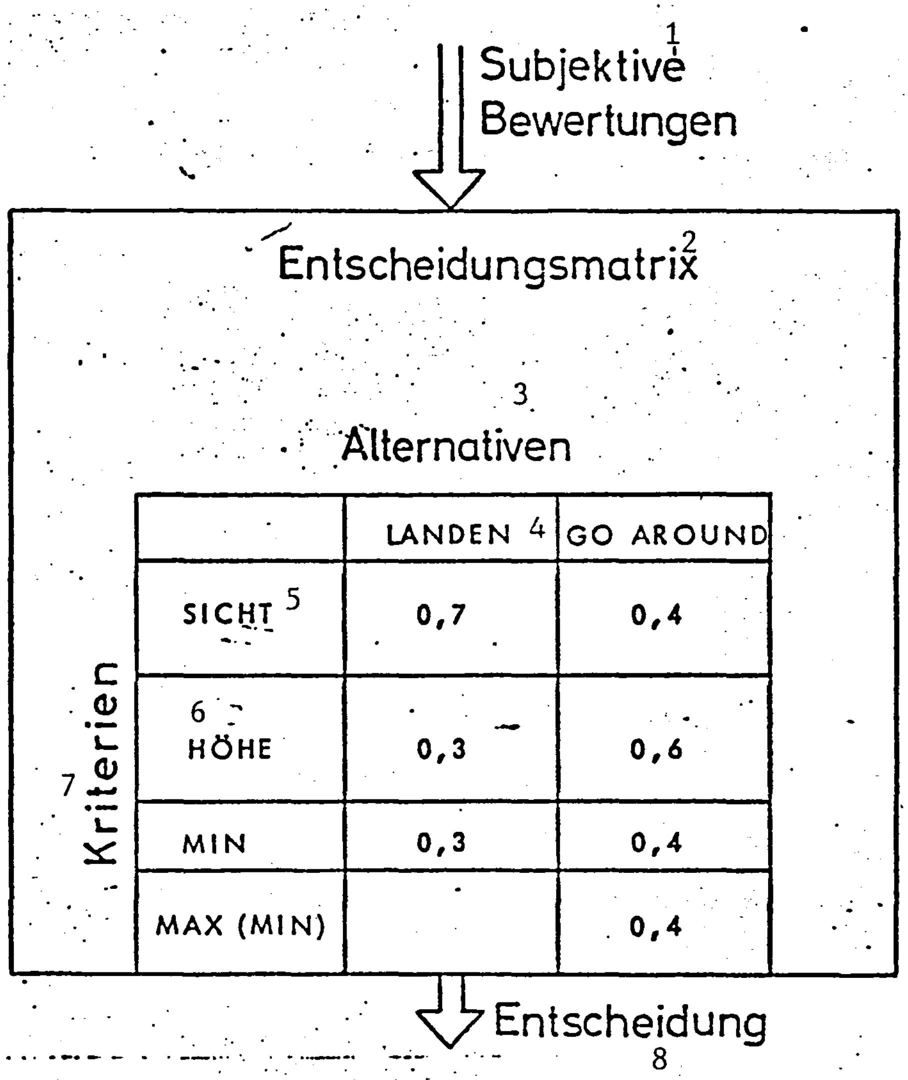
Fig. 3.1:Representation of the Crew System as a Waiting Loop Problem

Key: 1-supply file 2-task class 3-waiting loop 4-info. on overall system and processing status of the tasks 5-crew system

1 Funktions-spezifisch	2 Ablauf-spezifisch		Entscheidungs-parameter 3
	4 Aufgabe	5 Prozeß	
6 Zuordnung Aufgabe → Crewmember 10 Abhängigkeit von Aufgaben 14 Abhängigkeit von Ereignissen 13 Aufgabenpriorität	7 Form u. Kenngröße der Auftrittszeit-Verteilung 11 Form u. Kenngröße der Verteilung der Bearbeitungs-dauer	8 Form u. Kenngrößen der Auftrittszeitverteilung von Einzelereignissen	Form u. Kenngrößen 9 der Verteilung von Entscheidungszeit-punkten 12 Eingangsgrößen und Ergebnis der Entscheidung (zur Ermittlung des Entscheidungs-modells)

Fig. 3.2: Input Parameters of the Crew Simulation Model

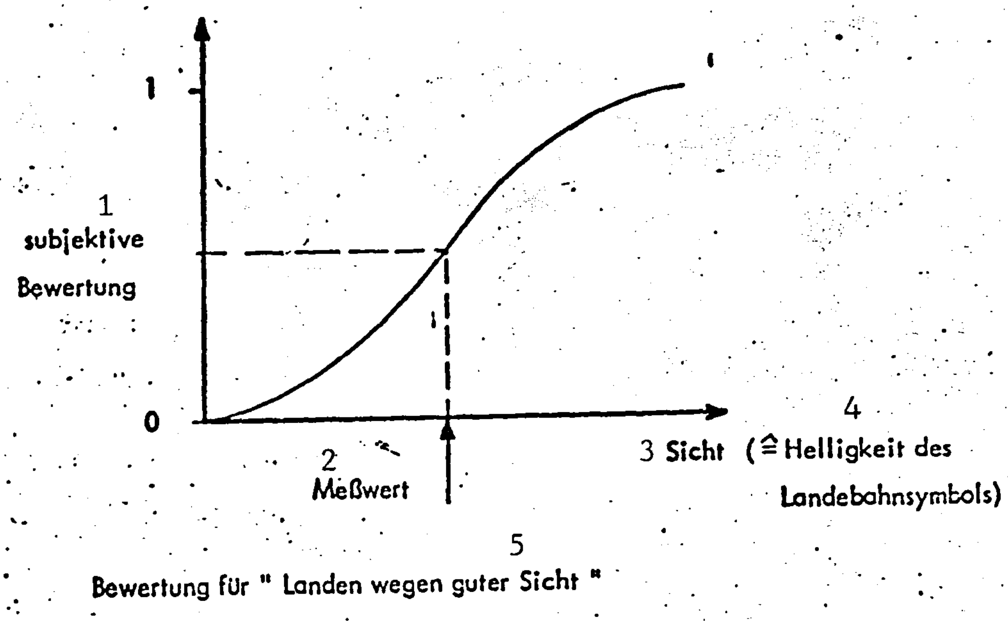
Key: 1-function-specific 2-task-specific 3-decision parameters 4-task 5-procedure 6-allocate task to crew member 7-form and characteristics of arrival-time distribution 8-form and characteristics of arrival-time distribution of individual events 9-form and characteristics of the distribution of decision timepoints 10-dependence of tasks 11-form and characteristics of the distribution of processing time 12-input quantities and result of the decision (to determine the decision model) 13-task priority 14-dependence on events



	LANDEN 4	GO AROUND
SICHT 5	0,7	0,4
6 HÖHE	0,3	0,6
MIN	0,3	0,4
MAX (MIN)		0,4

Fig. 3.3: Representation of the Critical Decision in Final Approach as a Decision Matrix from /3/.

Key: 1-subjective valuations 2-decision matrix 3-alternatives 4-land 5-visibility 6-altitude 7-criteria 8-decision



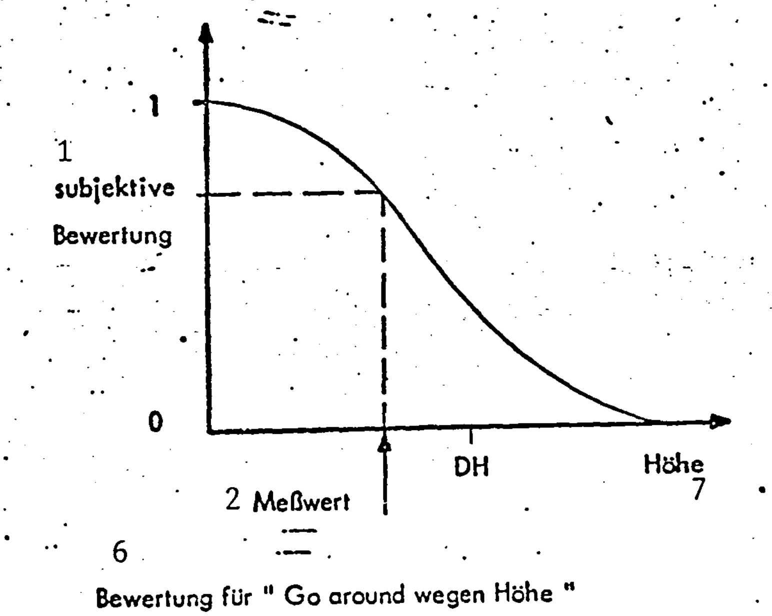
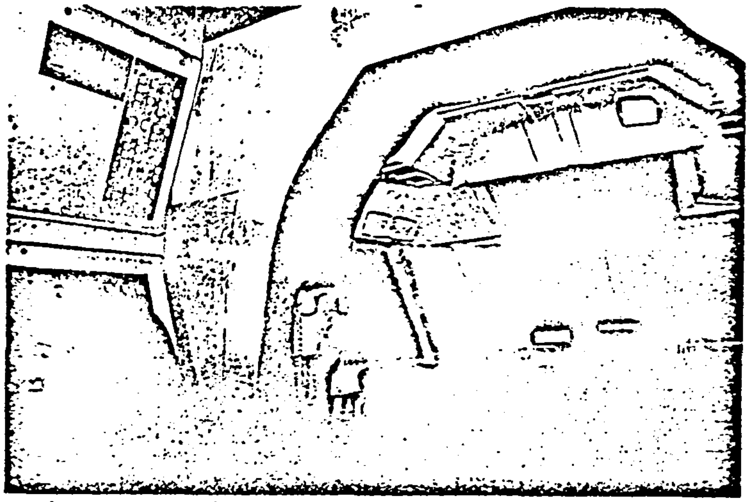
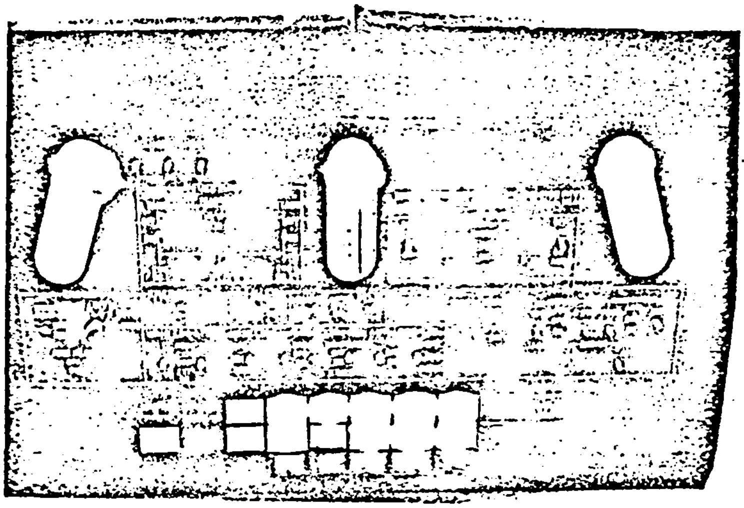


Fig. 3.4: Application of Evaluation Functions to the Determination of Subjective Evaluations from Measured Values

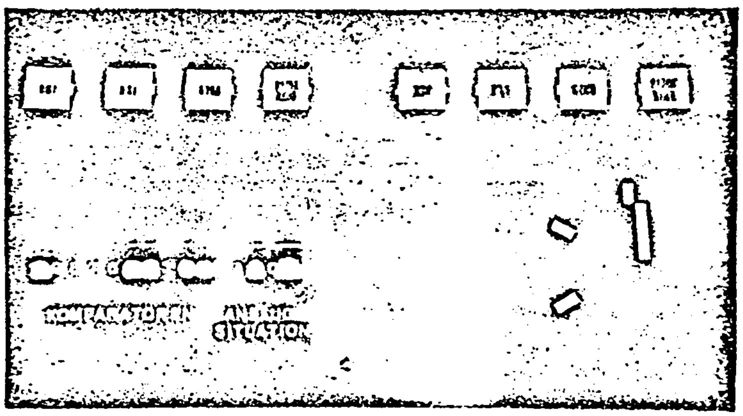
Key: 1-subjective evaluation 2-measured value 3-visibility 4-brightness of runway symbol 5-evaluation for "land due to good visibility" 6-evaluation for "go around due to altitude" 7-altitude



'a) Gesamtansicht



b) Overheadpanel



c) Bedien - und Überwachungseinheit: Instructor-Station

Fig. 4.1: Overhead Panel with Control & Monitoring Units

Key: a) overall view b) Overhead panel c) control & monitoring unit, instructor station

Gruppe = group

Gruppe A	- Panel Lights - Circuit Breakers - Fuel Pumps
Gruppe B	- Hydraulic Pumps - Emergency Lights - No Smoking/Seat belts Lights - Anti-Collision Light - Ignition - Ice Protect and fuel heat-System
Gruppe C	- External Lighting

Fig. 4.2: Overview of the Simulated Aircraft Systems Combined in the Overhead Panel

Group A: Systems affect the simulation via the simulator program and are checked by the monitoring logic

Group B: Systems are monitored only; no effect on the simulation

Group C: Pure dummys

Gruppe = group

Gruppe I	- Park Brake - Pic und F/O NAV
Gruppe II	- Fuel Heat - Igniters - De-icing - Pitot Heat

Fig. 4.3: Warning Lights in the Overhead Panel

Group I : Triggered by appropriate signal from the simulation program

Group II: Triggered by operating the pertinent switch in the overhead panel.

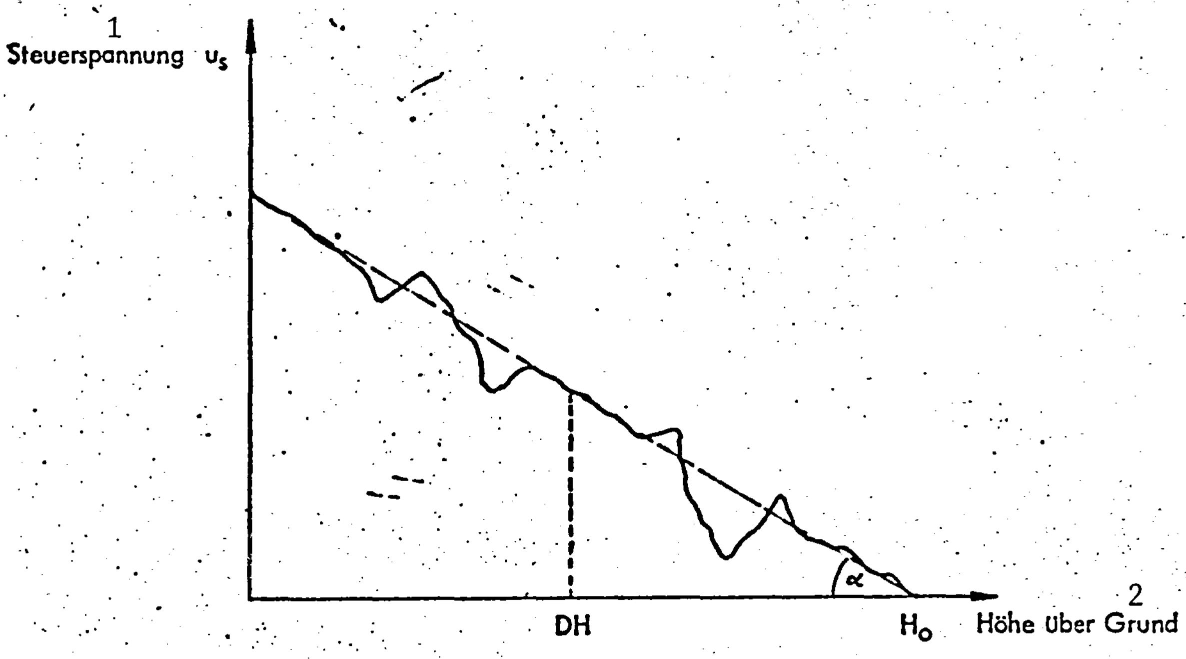


Fig. 4.4: Qualitative Brightness Profile of the Runway Symbol

Key: 1-control voltage   2-altitude above ground

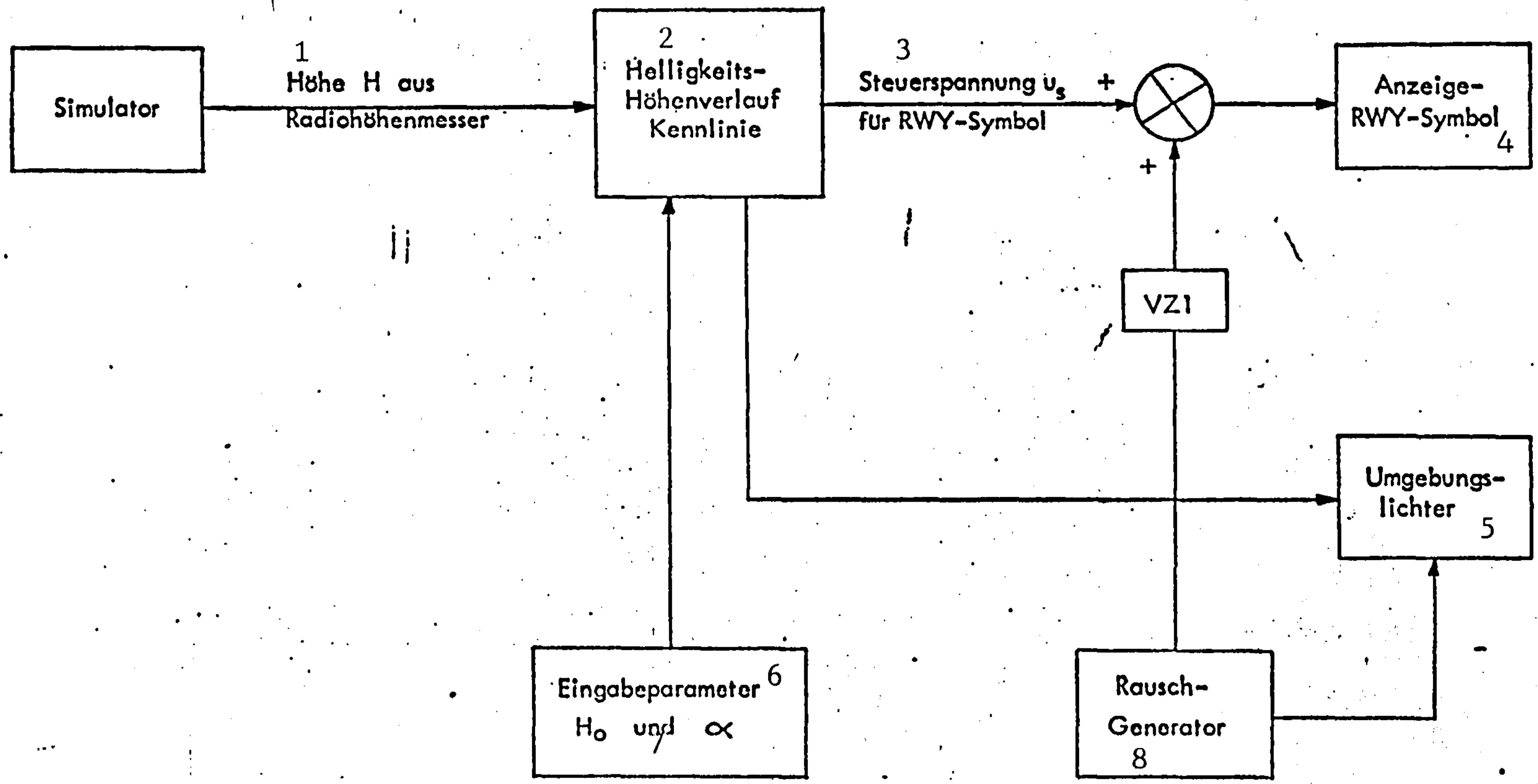


Fig. 4.5: Block Diagram of the Sighting Task for Final Approach

Key: 1-altitude H from radio altimeter 2-brightness-altitude profile line 3-control voltage for runway symbol 4-display of runway symbol 5-nearby lights 6-input parameters 7-and 8-noise generator

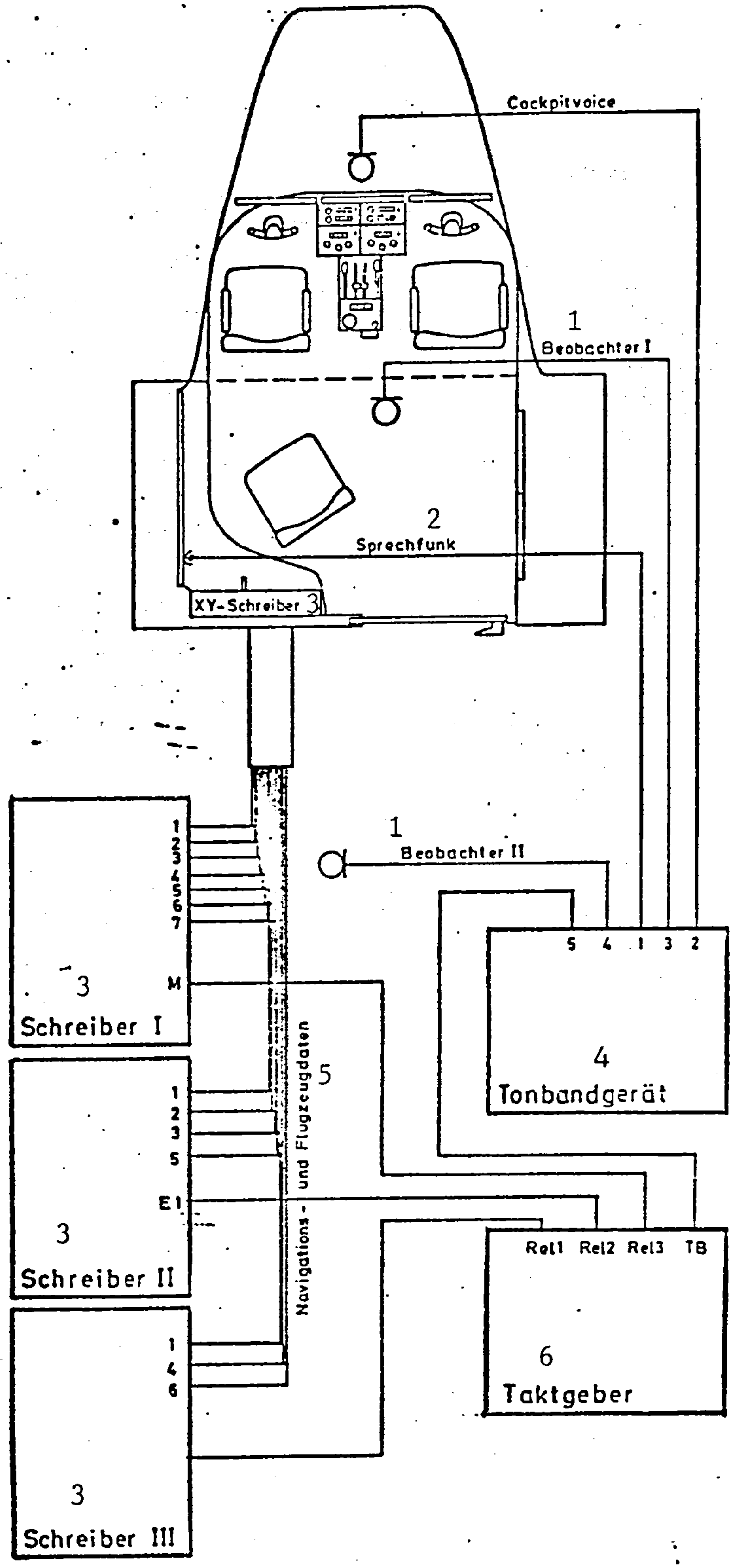
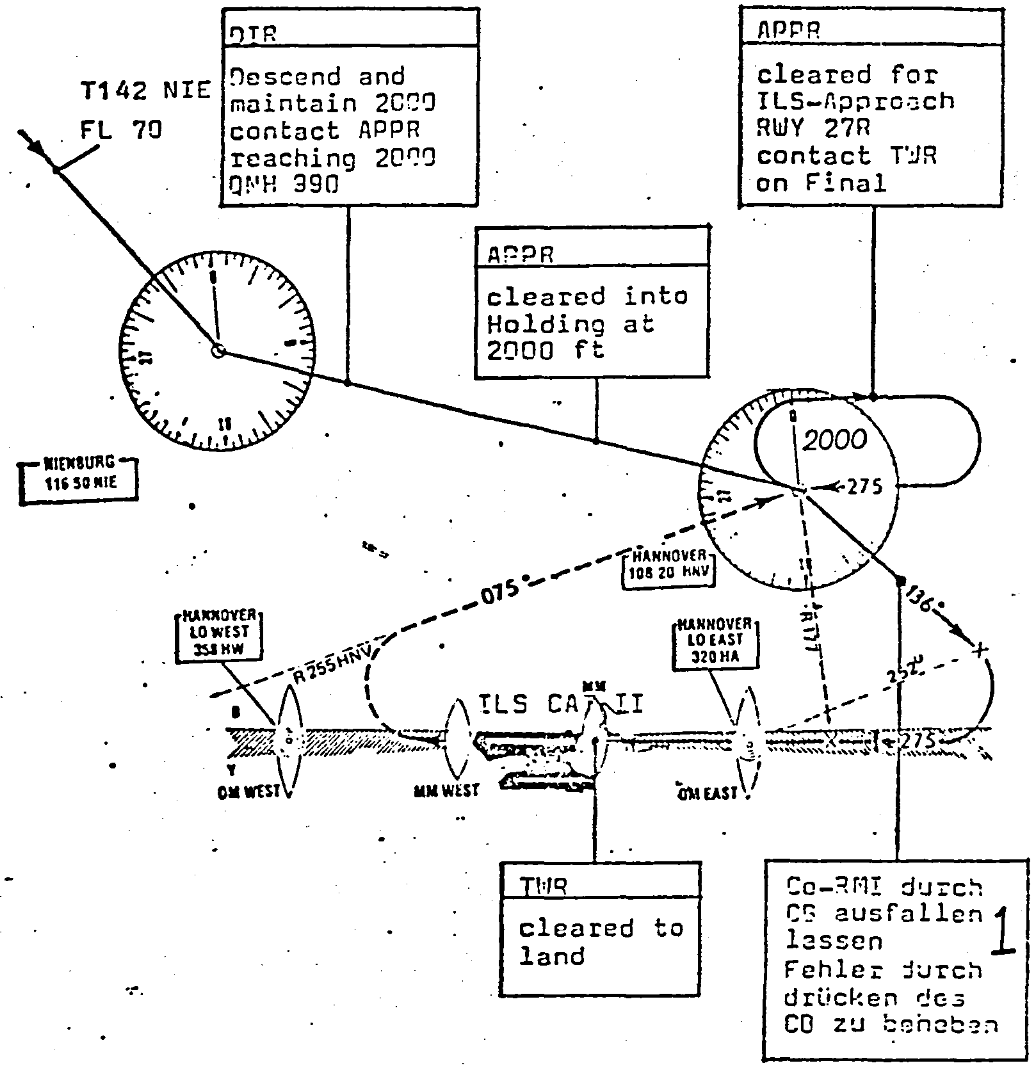


Fig. 4.6: Block Diagram of Data Acquisition Unit

Key: 1-observer 2-radio speech 3-plotter 4-tape recorder 5-navigation and aircraft data 6-clock



ceiling 1000 ft	fuel 2 t	G/W 32 t	
Sichtsim. 4,5/983 2	DIR 119.5	APPR 118.7	TWR 118.9
ATIS Foxtr.	QNH 990	Wind 180/1[illegible]	Temp. 15

Fig. 4.7: Example of a Test Plan

Key: 1-let Co-RMI fail due to CB. Correct fault by pressing the CB
2-visibility simulation

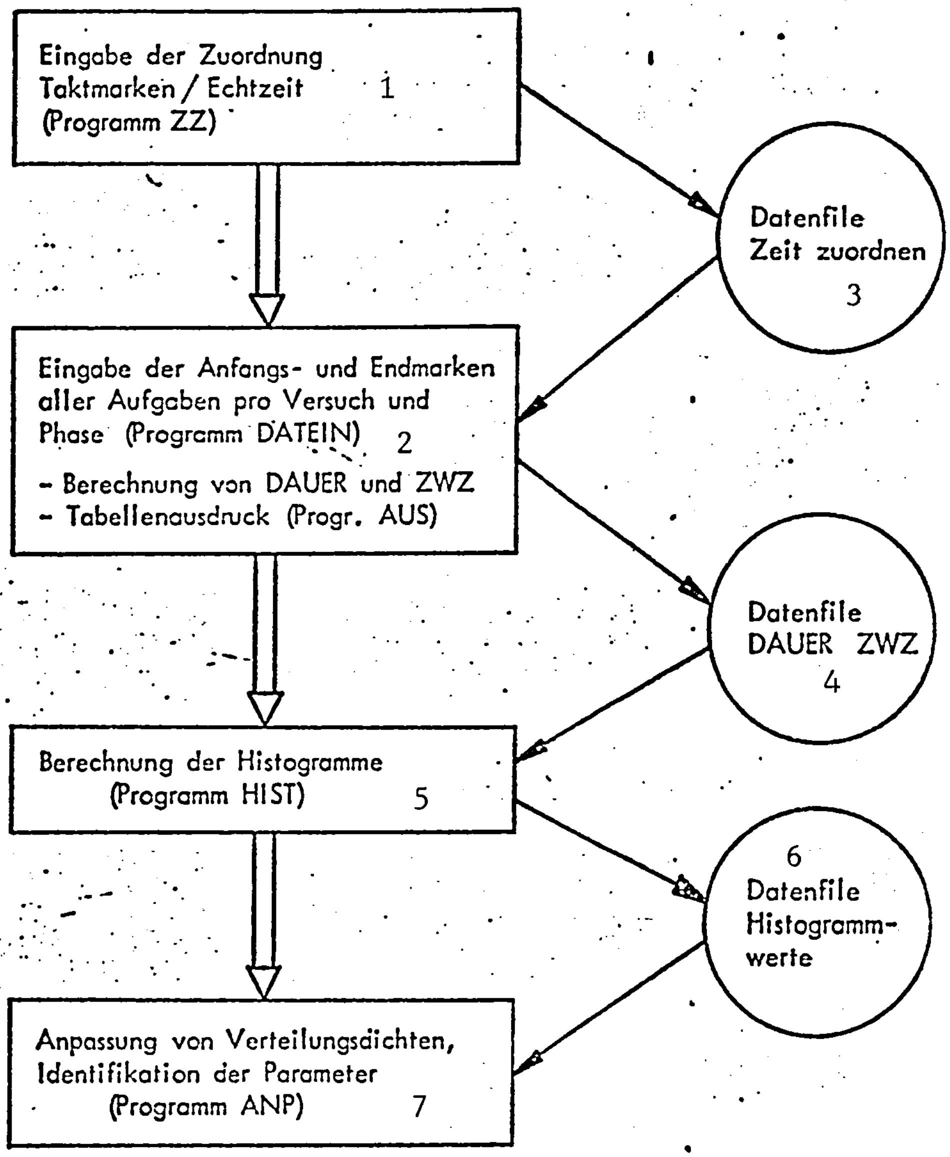


Fig. 4.8: Procedure for Storing and Evaluating the Test Data

Key: 1-input of allocation, clock marks/real time (program ZZ)
2-input of start and end marks of all tasks per test and phase (program DATEIN); calculation of DURATION and INTERARRIVAL time; tabular printout (program AUS)
3-assign data file to time
4-data file DAUER ZWZ
5-compute histogram (program HIST)
6-data file histogram values
7-adaptation of distribution densities, identification of parameters (ANP program)

1 ANFLUG NR 3 FLUGPHASE	2 VERSUCH NR 4 AUFGABE	3 ANF.MARKE 5	6 ENDMARKE	7 ANF.ZEIT [MIN]	8 ENDZEIT [MIN]	9 DAUER [SEC]	10 ZWZ [MIN]
3 FINAL	A 2, SINK EIN 11	124.00	126.80	0.82	1.17	20.88	0.82
		128.00	131.00	1.35	1.44	5.52	0.53
		140.10	140.70	2.25	2.32	4.32	0.90
		144.30	144.80	2.72	2.78	3.60	0.46
	12	148.70	149.30	3.24	3.32	4.50	0.53
3 FINAL	A 3, SINK AUS	120.30	124.00	0.35	0.82	28.44	0.35
		127.30	128.60	1.20	1.33	7.32	0.86
		131.00	133.40	1.44	1.64	11.76	0.24
		136.10	137.60	1.09	2.08	11.16	0.45
		142.00	142.50	2.50	2.56	3.30	0.61
		146.50	148.70	3.05	3.24	11.94	0.55
		149.30	149.60	3.32	3.36	2.34	0.27
3 FINAL	A 5, FINAL CH	123.20	125.00	0.70	1.09	23.40	0.18
3 FINAL	A16, QUERLAGE	115.50	123.50	0.06	0.74	41.10	0.06
		124.50	125.20	0.89	1.00	6.30	0.83
		125.70	127.30	1.07	1.20	7.74	0.18
		130.10	131.60	1.39	1.51	7.02	0.32
	13	133.40	138.50	1.64	2.14	30.24	0.24
		140.20	141.90	2.26	2.49	13.32	0.63
3 FINAL	A25, SPRECHFU	136.50	137.70	1.94	2.09	9.06	1.94
		142.00	143.50	2.50	2.64	8.70	0.56
3 FINAL	A27, GEAR	121.00	121.20	0.43	0.46	1.80	0.11
3 FINAL	A28, FLAPS	119.00	120.40	0.31	0.36	3.12	0.08
		123.30	124.30	0.72	0.86	9.00	0.19
3 FINAL	A29, KOMMUNIK 14	137.70	140.00	2.09	2.24	8.94	2.09

Fig. 4.9: List of Test Data Determined from the Measurement Records (fig. 2.5) (phase 3, 3rd approach to HNV 27 R)

Key: 1-approach no. 2-test no. 3-flight phase 4-task 5-begin mark 6-end mark 7-begin time 8-end time 9-duration 10-interarrival time 11-descent on 12-descent off 13-radio comm. 14-communications

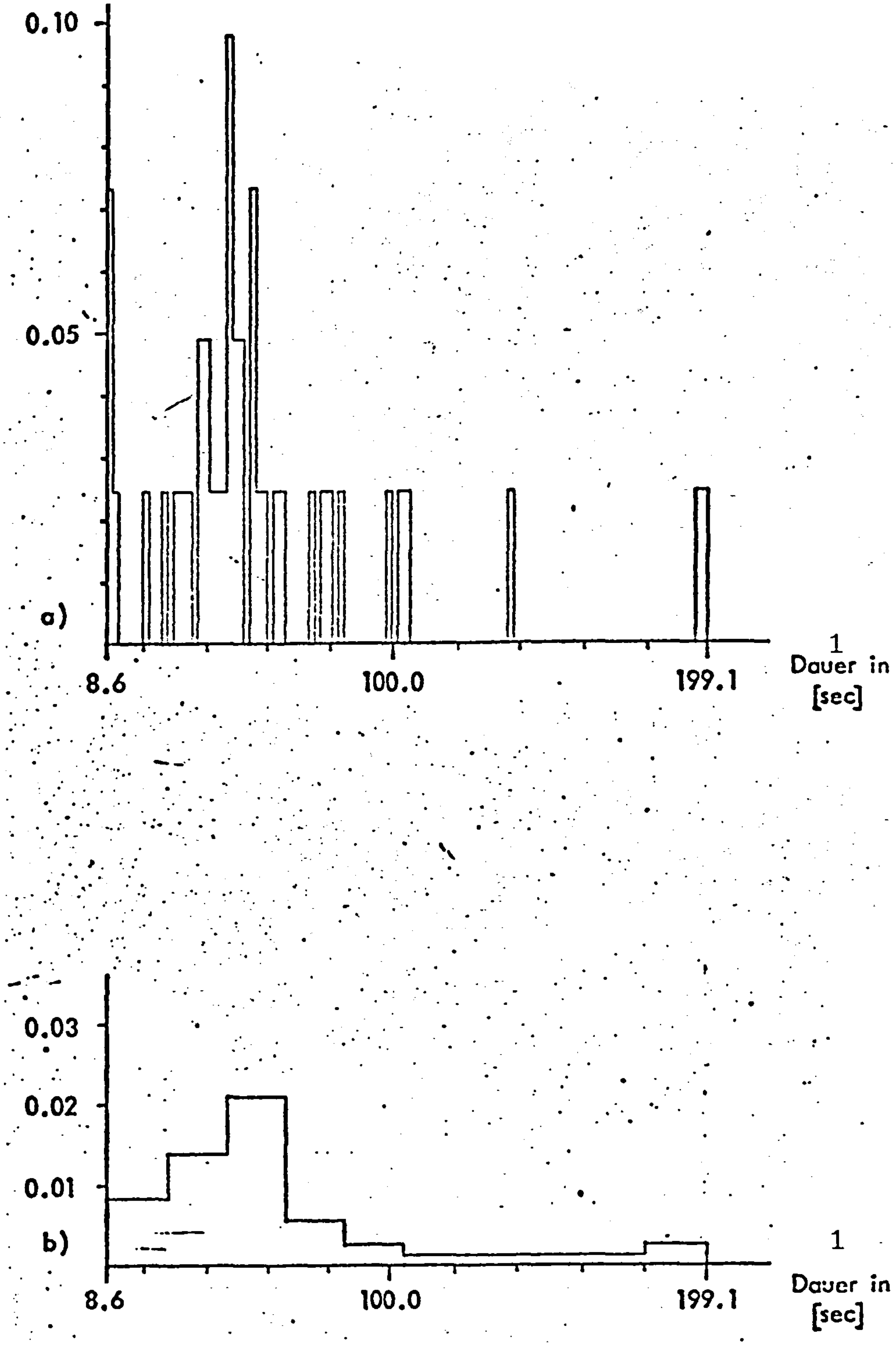


Fig. 4.10: Histogram (a) and "measured distribution density" (b) for the duration of task "Approach Check" in phase 2.

Key: 1-duration in seconds

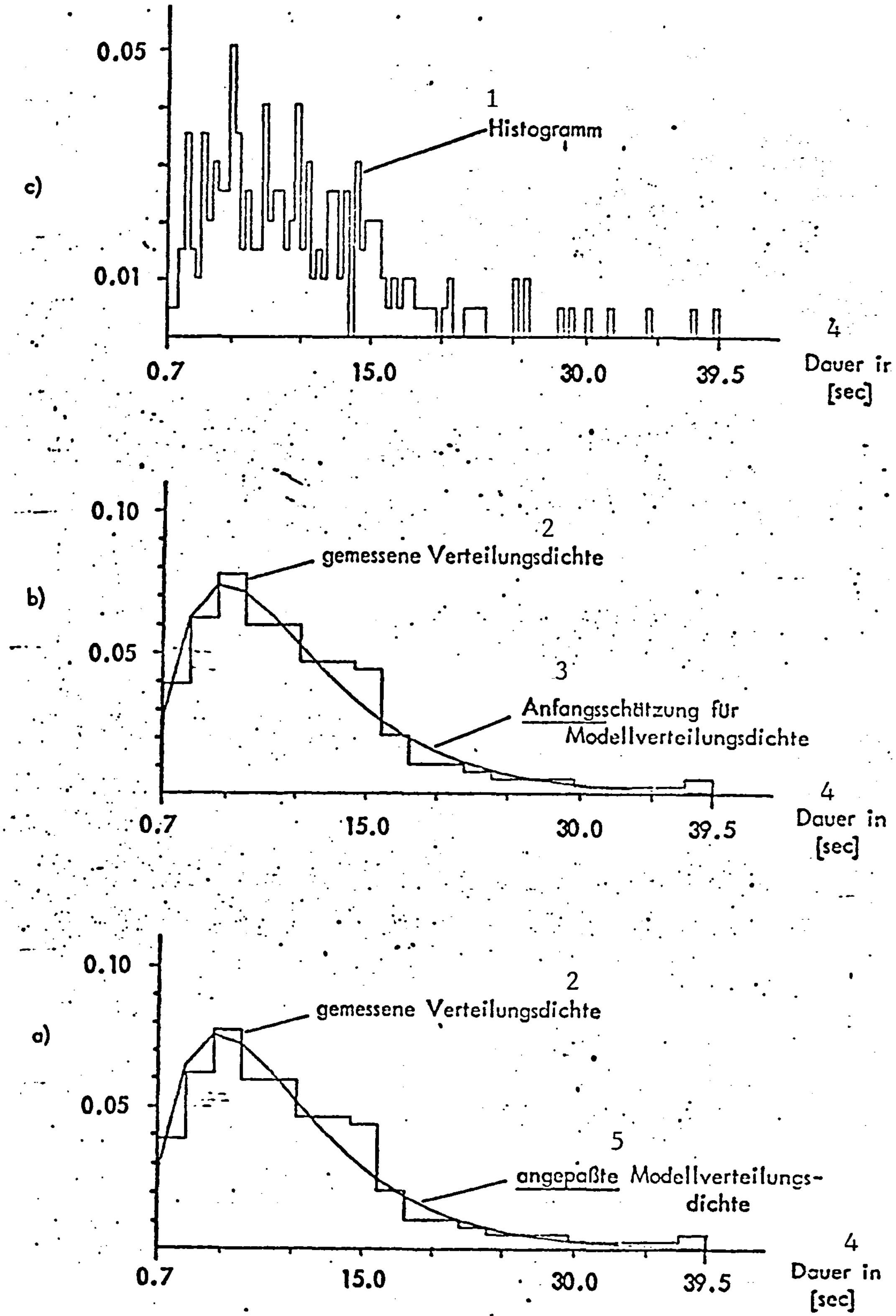


Fig. 4.11: Histogram, measured and adapted Distribution density using the example of the duration of task 2 from operating phase 2.

Key: 1-histogram 2-measured distribution density 3-initial estimation for model distribution density 4-duration 5-adapted model distribution density

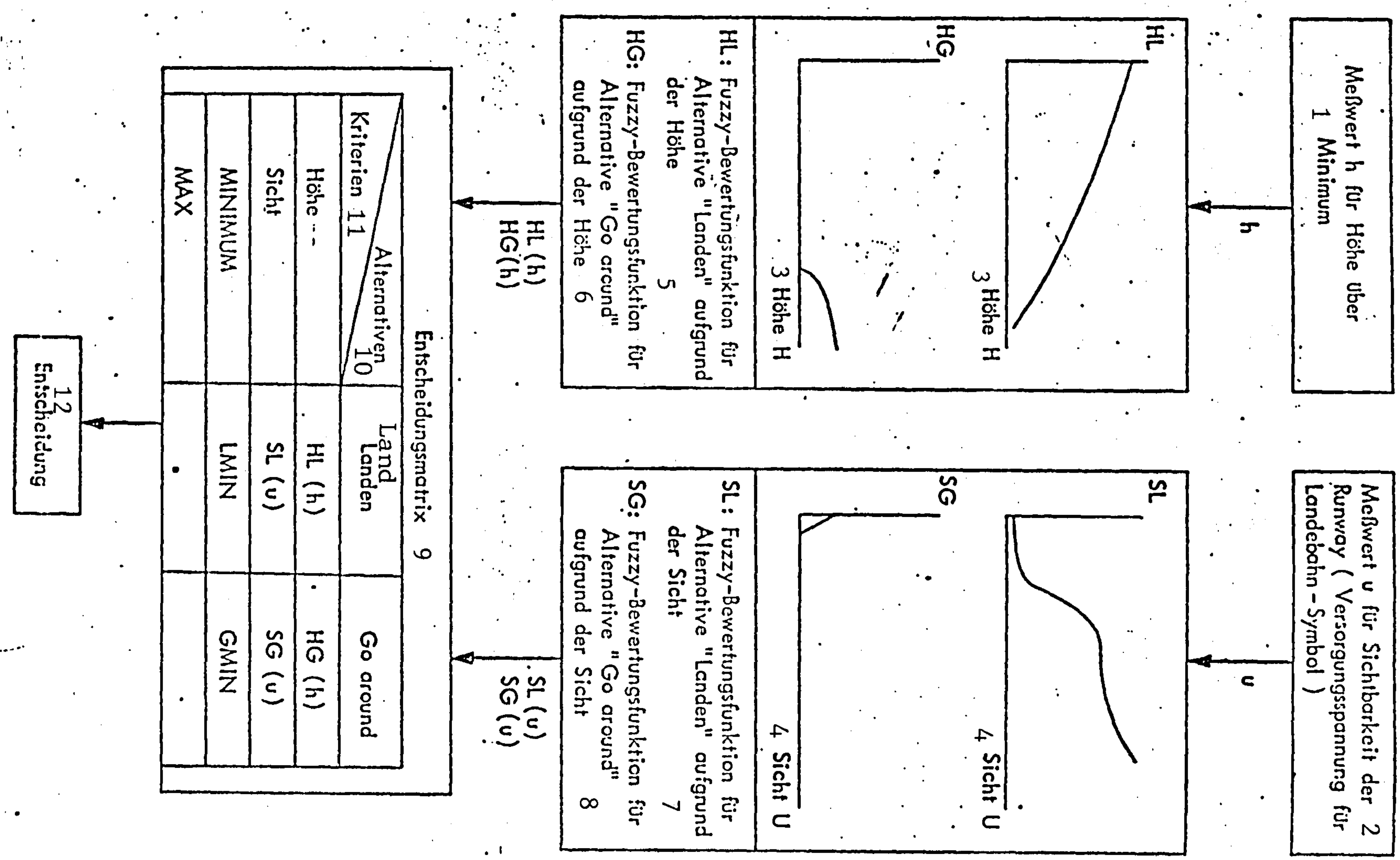


Fig. 4.12: Representation of the Simulation of the "Critical Decision" in landing ... (text missing).

Key: 1-measured value h for altitude above minimum 2-measured value u for visibility of the runway (supply voltage for runway symbol) 3-altitude 4-visibility
5-fuzzy evaluation function for alternative "land" based on altitude
6-fuzzy evaluation function for alternative "go around" based on altitude
7-fuzzy evaluation function for alternative "land" based on visibility
8-fuzzy evaluation function for alternative "go around" based on visibility
9-decision matrix 10-alternatives 11-criteria 12-decision

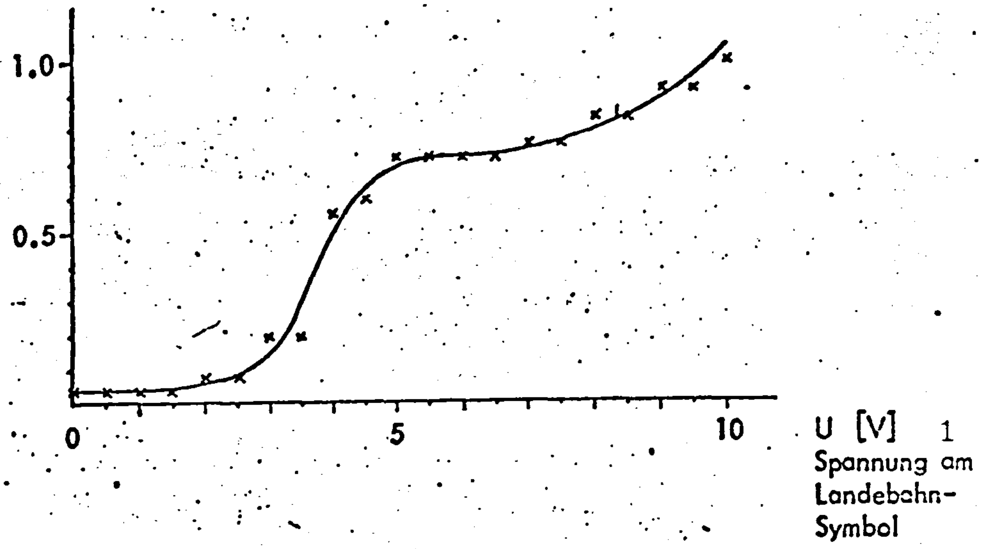


Fig. 13a: Fuzzy Evaluation Function for the Alternative "Land" based on the criterion "Visibility"

Key: 1-voltage to the runway symbol

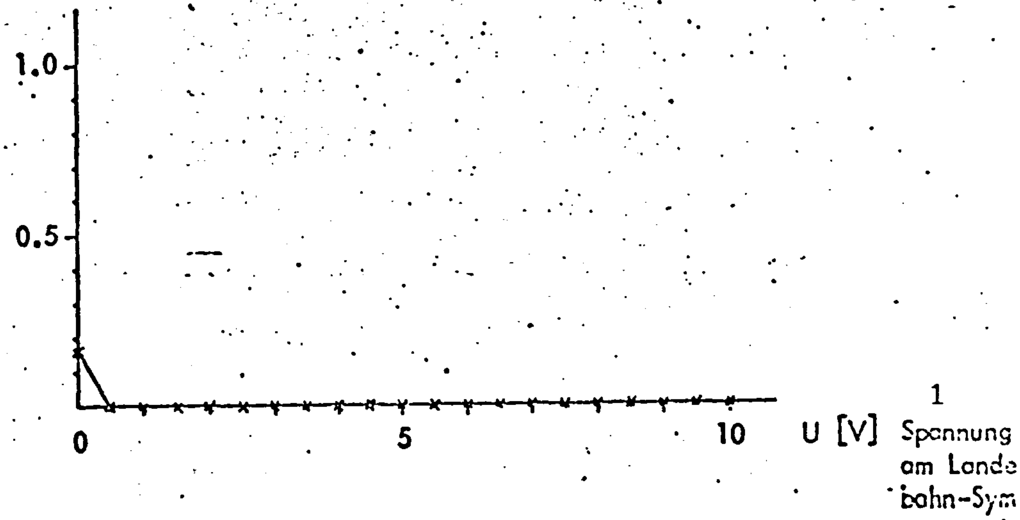


Fig. 4.13b: Fuzzy Evaluation Function for the Alternative "Go around" based on the criterion "Visibility"

Key: 1-voltage to the runway symbol

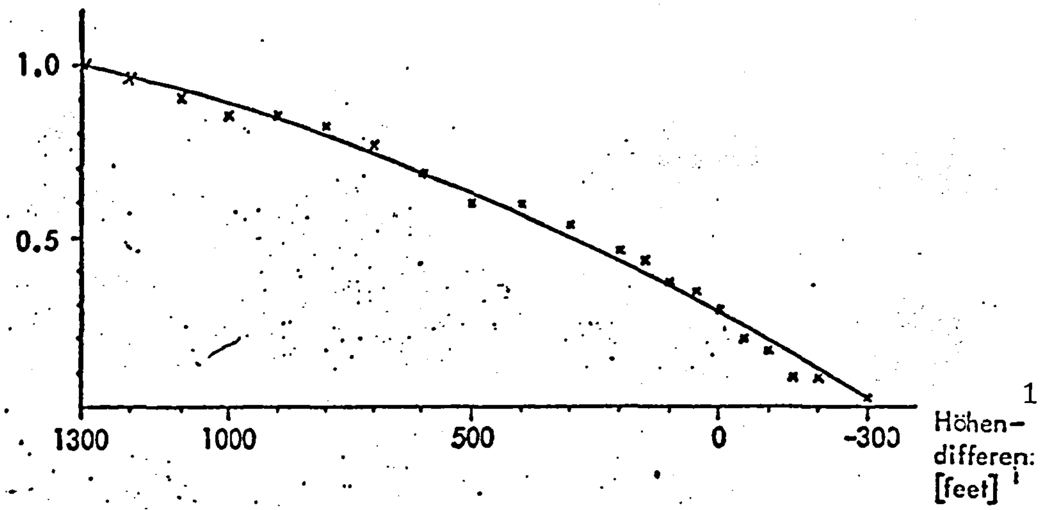


Fig. 4.14a: Fuzzy Evaluation Function for the Alternative "Land" based on the criterion "altitude"

Altitude difference = present altitude - decision minimum

Key: 1-altitude difference

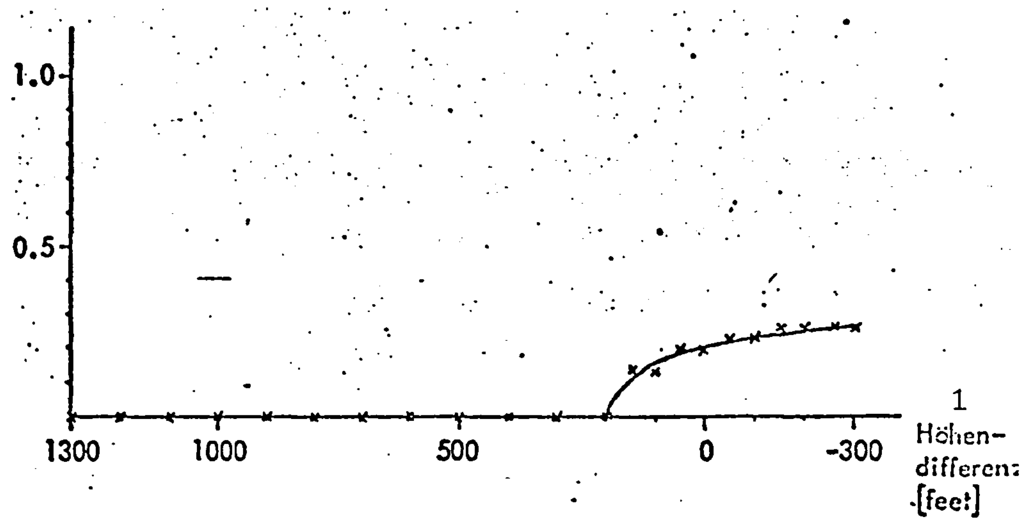


Fig. 4.14b: Fuzzy Evaluation Function for the Alternative "Go Around" based on the criterion "Altitude"

Altitude difference = present altitude - decision minimum

Key: 1-altitude difference

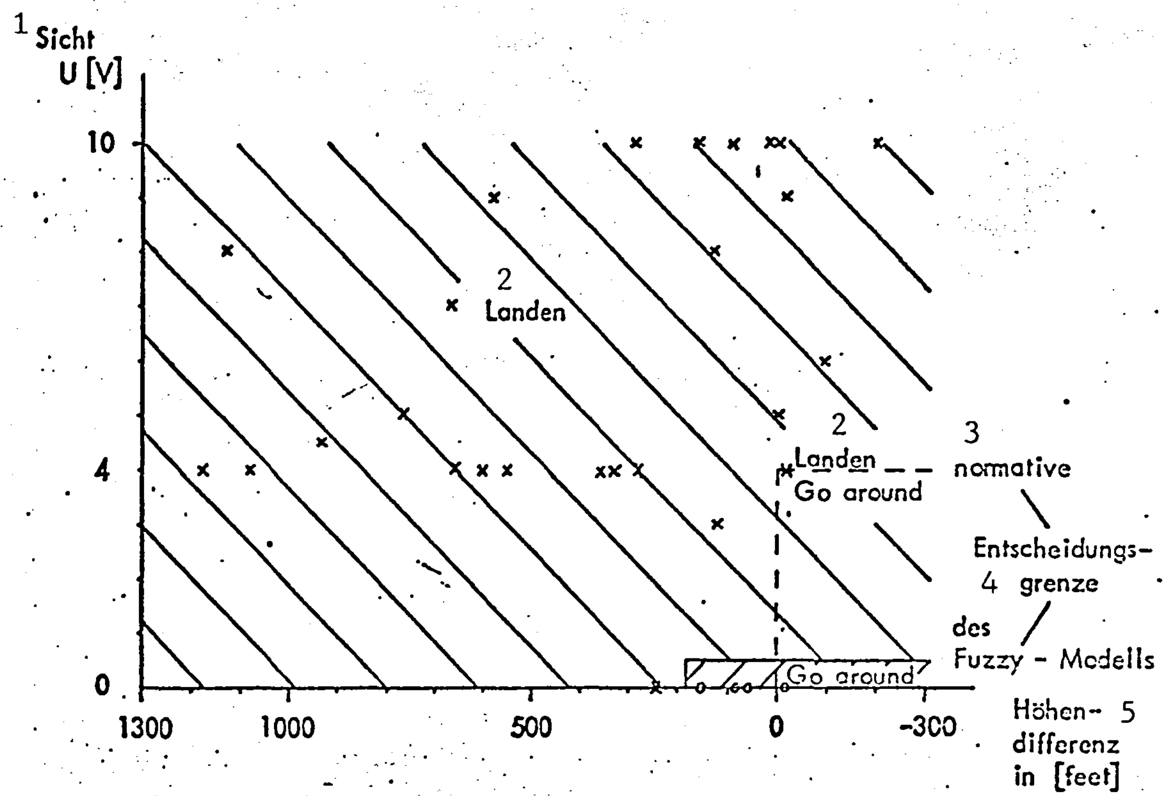
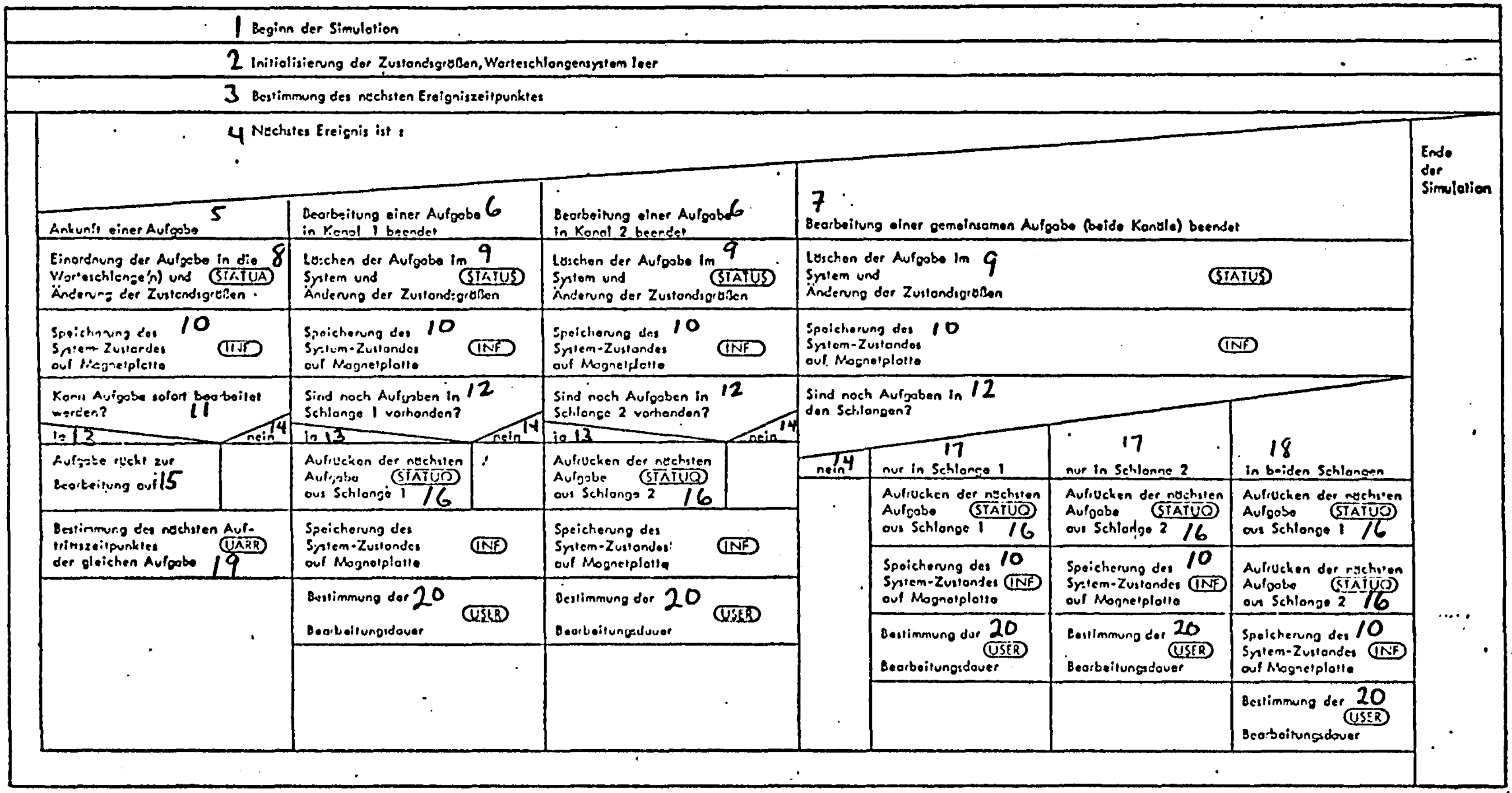


Fig. 4.15: Representation of the Normative, Measured and Modeled Decisions plotted agianst the measurable (objective) Criteria
(x decision for F.I.S. or CONTINUE on the simulator
o decision for Go around on thesimulator)

Key: 1-visibility 2-land 3-normative 4-decision limit of the fuzzy model 5-altitude difference



Key: 1-beginning of simulation 2-initializing of quantities of state, waiting loop system empty 3-determination of next event timepoint 4-next event is 5-arrival of a task 6-processing of a task in finished in channel 7-processing of a joint task (both channels) is finished 8-placement of task into the wailing loop and change of quantities of state 9-cancel task in the system and change of quantities of state 10-storage of system status on magnetic disc 11-can task be processed immediately? 12-are there still tasks in loop? 13-yes 14-no 15-task moves up for processing 16-the next task moves up from loop 17-only in loop 1 (2) 18-in both loops 19-determination of the next arrival time of the same task 20-determination of processing time

Fig. 5.1: Structure of the CQS Subprogram

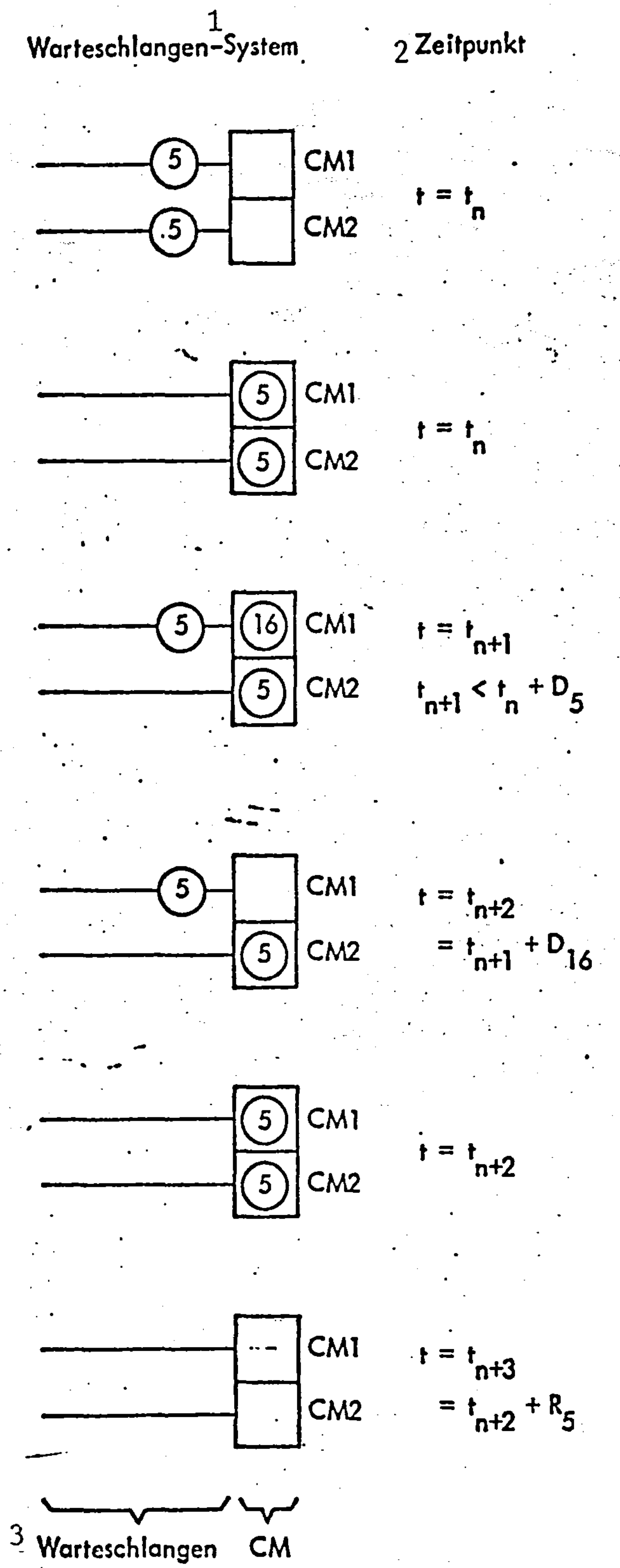


Fig. 5.2: Example of a Sequence of Actions in phase 3 with a "joint" pilots' task and a task of absolute priority. Representation of the fundamental operation of the waiting-loop model.

Key: 1-waiting loop system 2-timepoint 3-waiting loops

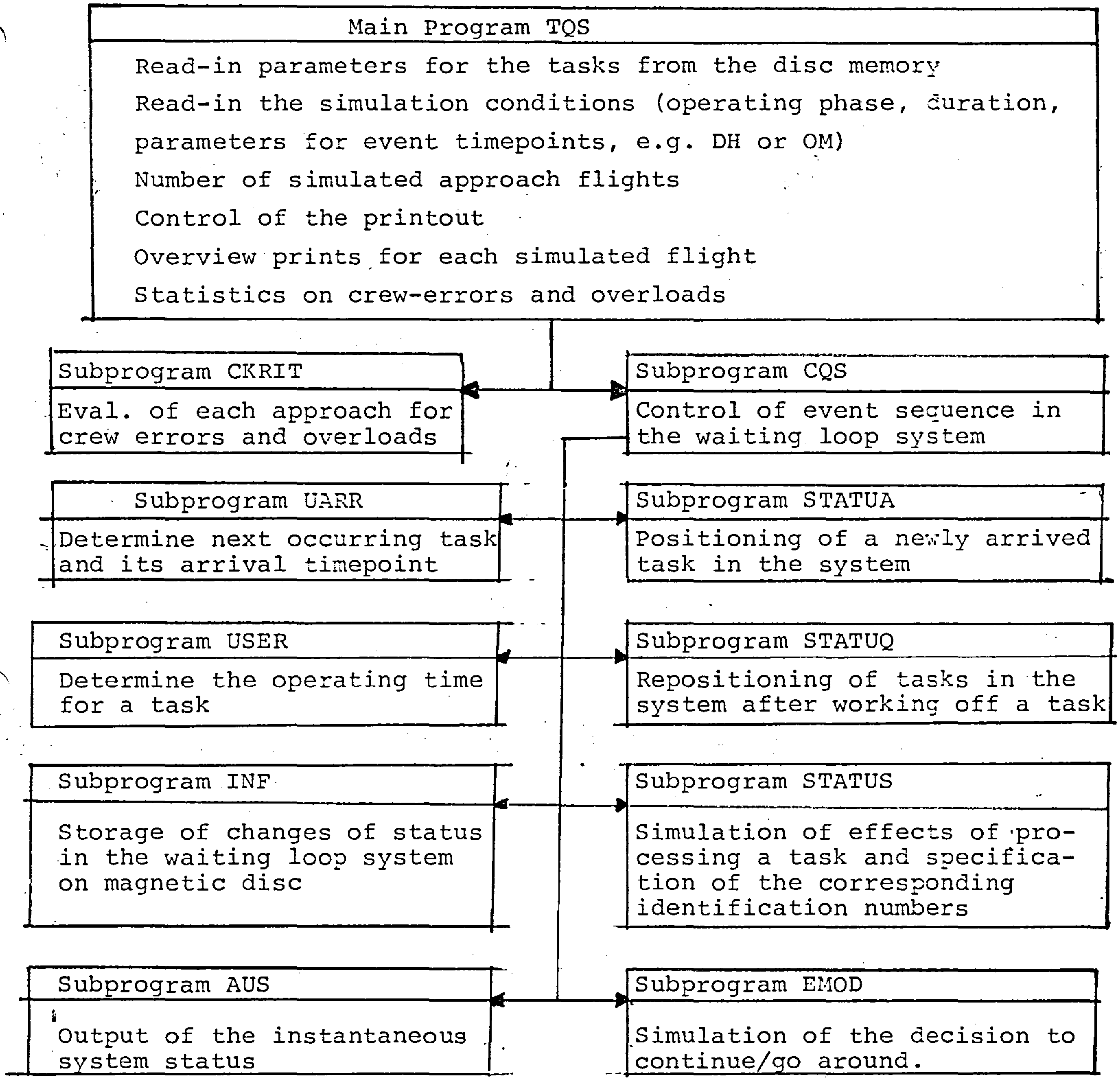


Fig. 5.3: Structure of the Program Packet to Simulate the Action Sequences in the Cockpit in the Waiting Loop System

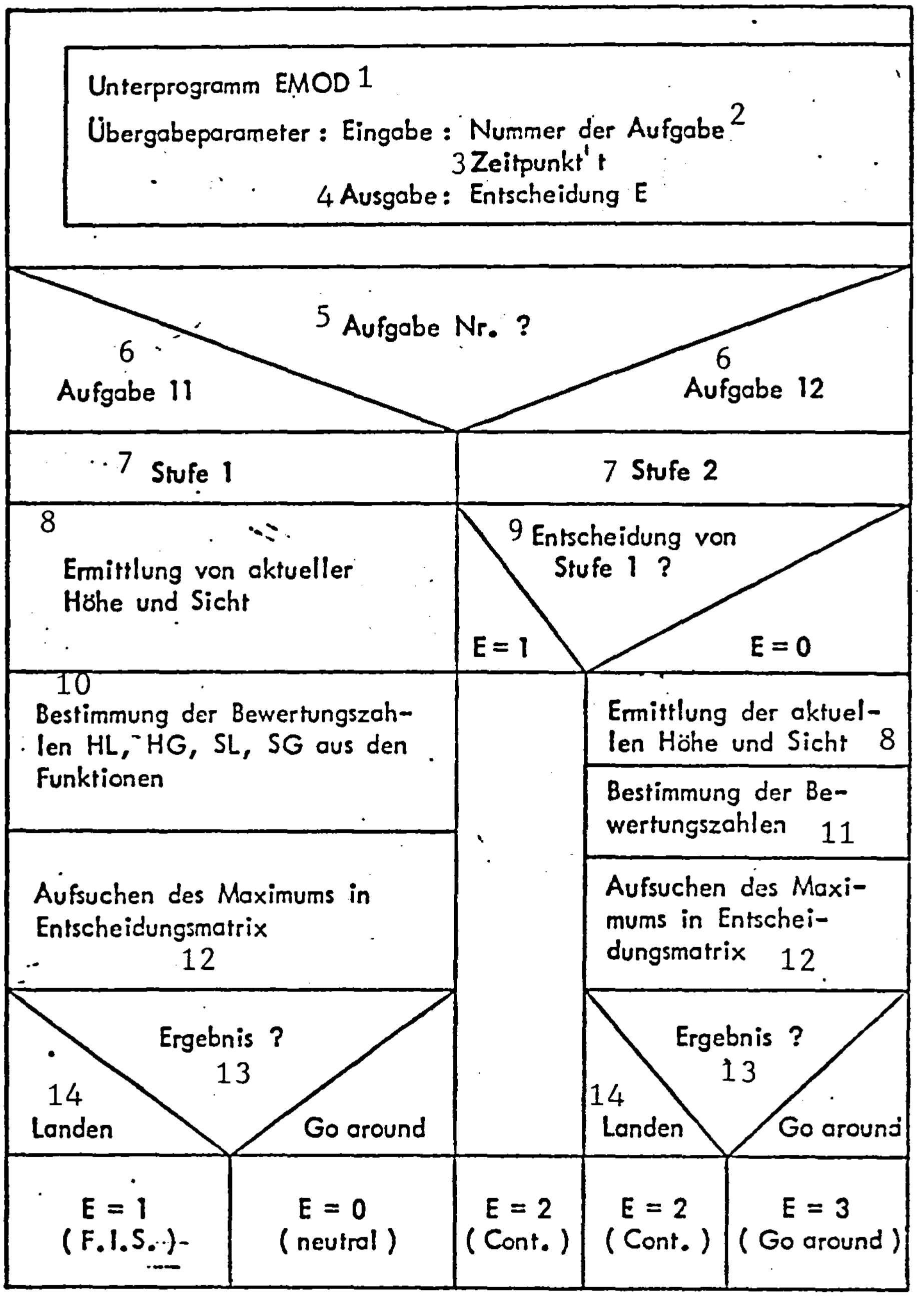


Fig. 5.4: Structure of the Subprogram EMOD (Simulation of the Landing decision on the computer in 2 stages)

Key: 1-subprogram EMOD 2-transfer parameters: Input: Number of tasks 3-timepoint 4-output: Decision 5-task no. 6-task 7-step 8-determination of present alt. and visibility 9-decision of step 1; 10-determination of eval. numbers HL, HG, SL, SG from the functions 11-determin. of eval. numbers 12-seek maximum in decision matrix 13-result 14-land

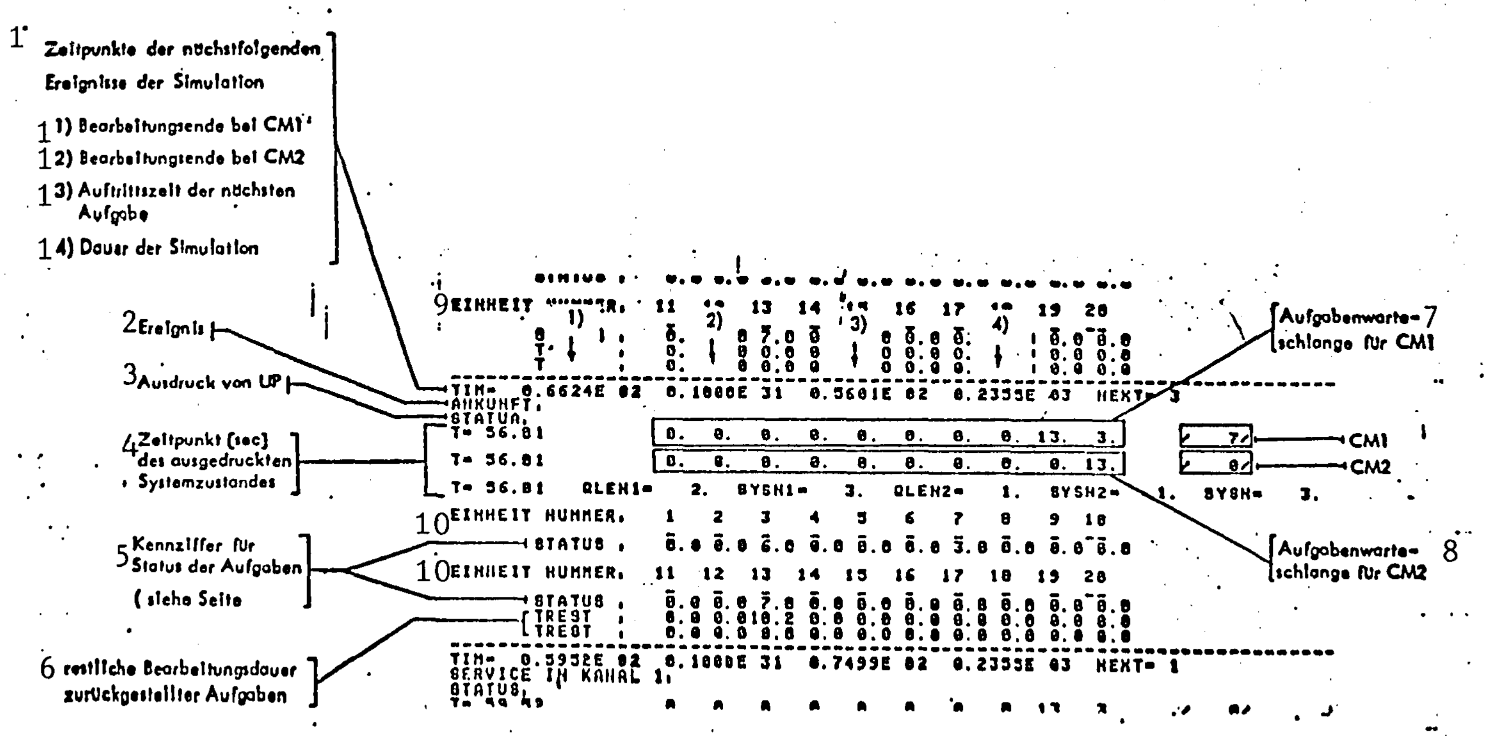


Fig. 5.5: Detailed Printout of the Simulation Program (Excerpt for an event timepoint)
Task 3 = begin descent; task 7 = change rudder; task 13 = communication

Key: 1-timing of the next event of the simulation 2-event 3-output of UP 4-timing of the output system status 5-id. for status of tasks (see page..) 6-remaining processing time for kicked-back tasks 7-task waiting loop for CM1; 8-task waiting loop for CM2 9-unit 10-unit number 11-processing end for CM1; 12-processing end for CM2; 13-channel 14-duration of the simulation

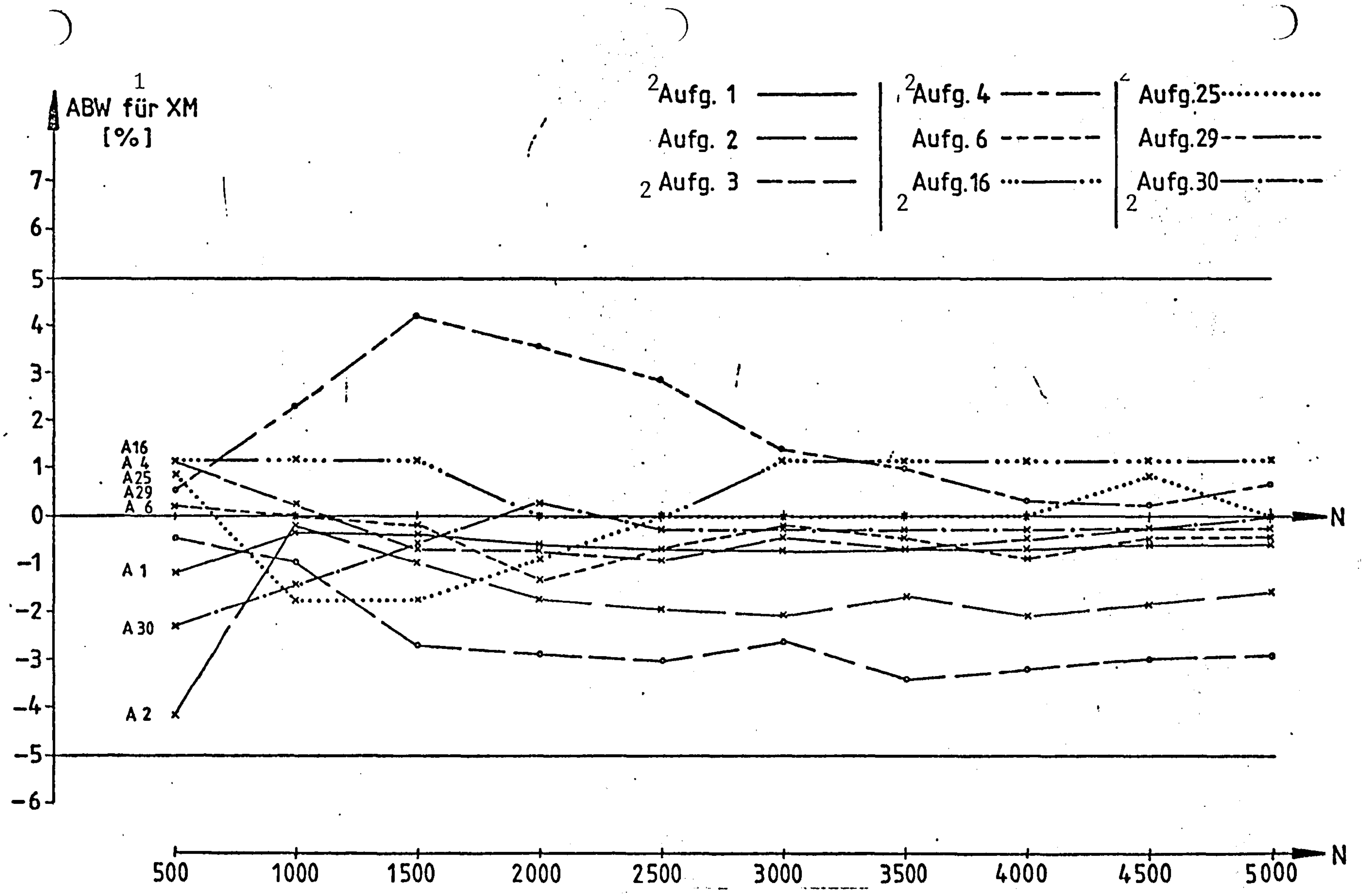


Fig. 5.6: Deviation of the Average XM from the Desired Value of the Distribution for the Simulated Processing Duration Plotted Against the Number of Measured Values N.

Key: 1-for 2-task

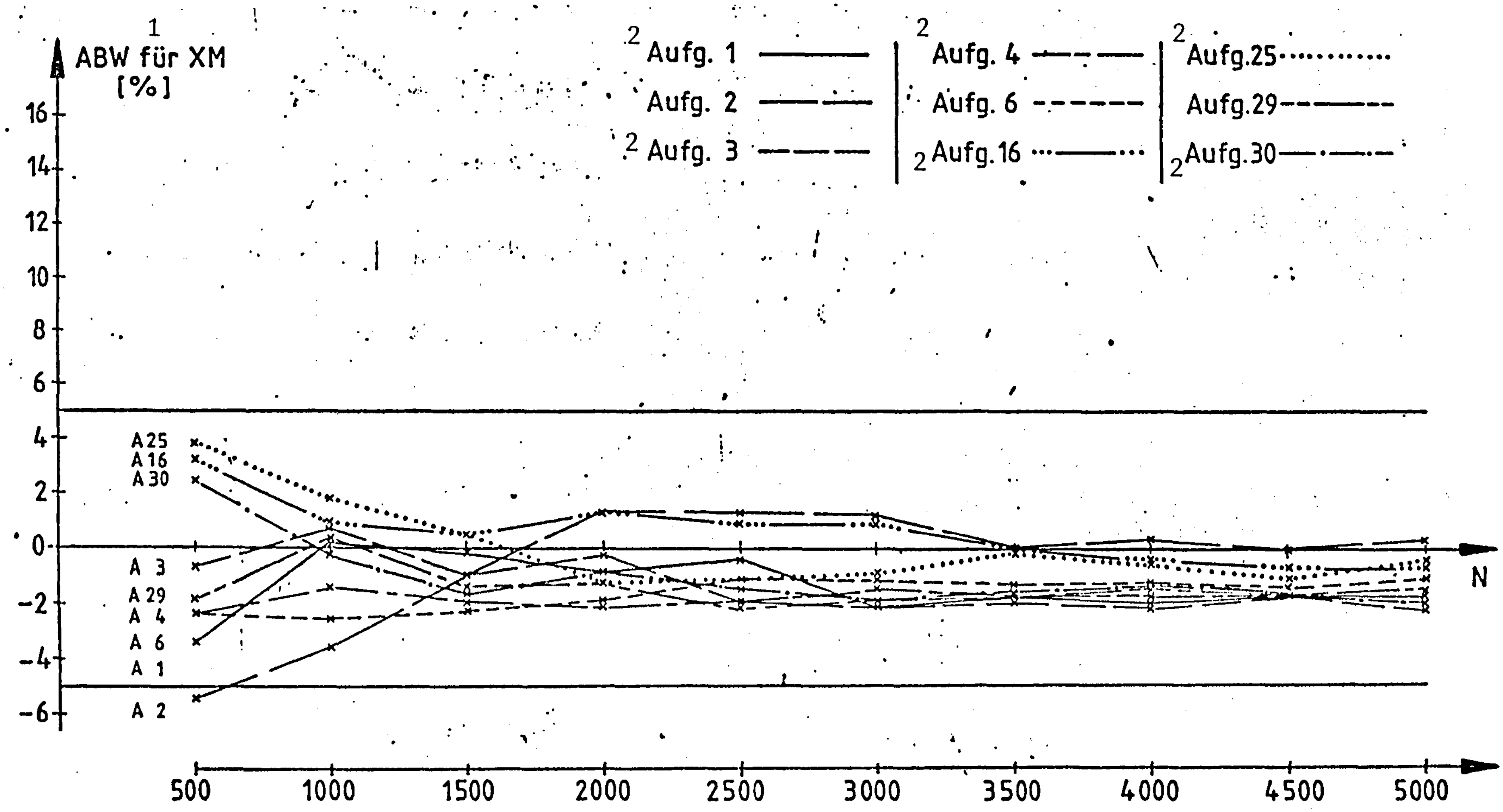


Fig. 5.7: Deviation of the Average Value XM from the Desired Value of the Distribution for the Simulated Interarrival time Plotted Against the Number of Measured Values N

Key: 1-for 2-task

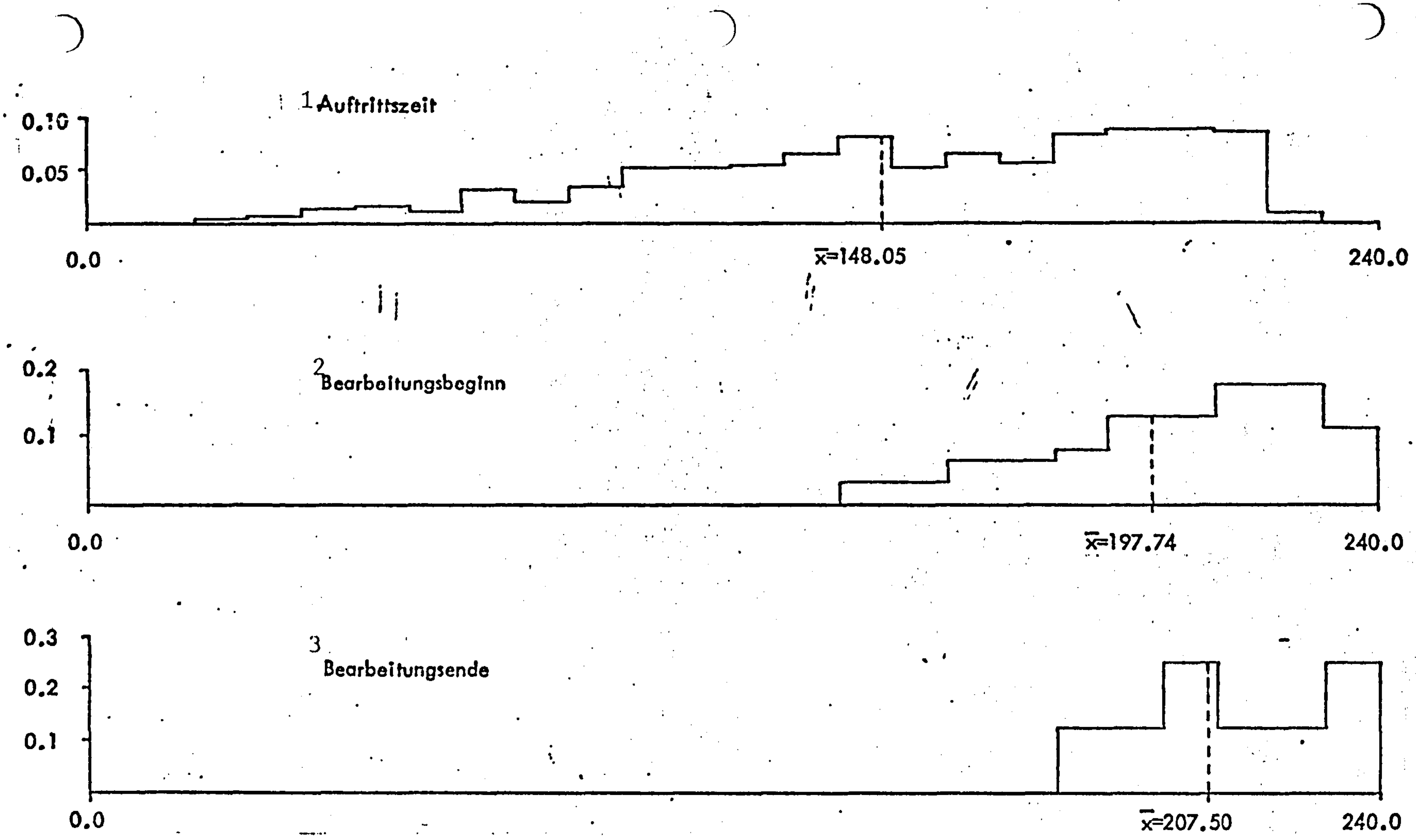


Fig. 5.8: Histogram for the Event Times of Task 4 (Approach Check) from Computer Simulation (test series 1)

Key: 1-arrival time 2-beginning of processing 3-end of processing

Table 4.1: Approaches and Test Conditions for Flight Simulator Test Series

ANFLUG NR [1]	01	02	03	04	05	06
AUF FLUGHAFEN/RWY [2]	HAM 05	BMN 27	HAM 23	HNV27R	KB032R	DUS 06
ART DES ANFLUGES [3]	NDB	VOR	ILS	ILS	ILS	VOR
SICHTBEDINGUNGEN [4]*	1000/1	0700/2	0100/2	1000/1	0100/2	1000/2
ATIS KENNZEICHEN [5]	BRAVO	SIERRA	CHARLY	FOXTROTT	BRAVO	ALPHA
RUNWAY IN USE	05	27	23	27R+L	32R	06
TRANSITION LEVEL	50	60	50	60	60	50
WIND [DGR/KN]	100/05	210/25	CALM	180/10	290/05	CALM
VISIBILITY [KM]	3.0	1.0	1.8	3.0	0.5	10.0
RVR [KM]	6.0	2.0	1.6	4.0	0.9	15.0
CLOUDS [OCTA/FEET]	2/1000	8/0700	8/0300	6/1000	6/0500	4/2000
TEMPERATURE [DGR C]	5	10	8	15	10	3
DEWPOINT [DGR C]	3	9	5	10	8	2
QNH [MB]	1024	993	1005	998	998	1009

ANFLUG NR [1]	07	08	09	10	11	12
AUF FLUGHAFEN/RWY [2]	KB014L	DUS 24	TOF27L	TGL08R	TOF09R	TGL26R
ART DES ANFLUGES [3]	ILS	NDB	VOR	ILS	VOR	ILS
SICHTBEDINGUNGEN [4]*	1500/1	0900/0	1600/1	0400/1	2000/0	1400/1
ATIS KENNZEICHEN [5]	LIMA	FOXTROTT	CHARLY	MIKE	QUEBECK	KILO
RUNWAY IN USE	14L	24	27L	08R	09R	26R
TRANSITION LEVEL	50	50	60	70	70	70
WIND [DGR/KN]	180/20	260/15	CALM	090/06	120/05	190/09
VISIBILITY [KM]	3.0	6.0	9.0	0.6	7.0	8.0
RVR [KM]		5.0		0.4		
CLOUDS [OCTA/FEET]	6/4000 4/1500	2/1000 6/3000	5/2000	7/0500	5/6000 7/11000	1/5000 7/10000
TEMPERATURE [DGR C]	18	12	11	10	11	10
DEWPOINT [DGR C]	10	11	6	4	6	5
QNH [MB]	1015	1019	1025	1009	1004	1003

*Explanation of data on visibility conditions "H/P"

H = alt. in ft above ground where the runway symbol is to attain max. brightness

P = parameter for qual. description of brightness change of runway symbol when approaching runway

P = 0: Slow increase; P = 1: Moderate Increase; P = 2: Fast increase

Key: 1-approach no. 2-to airport/runway 3-type of approach 4-visibility conditions 5-ATIS id.

Table 4.2: Test Plan for Approaches for the Flight Simulator Test Series

1 Zielflughafen/RWY (Versuch Nr.)	2 von	Anweisung 4 Zeit 3	Inhalt 5	Besondere Vorkommnisse 6 Zeit 3	Art 7
HAM 16 (1)	DIR	1. Kontakt 8	Descend and maintain 3500 QNH 1023 contact HAM Appr. on 120.60 reaching HTF NDB		
	APP	1. Kontakt 8	Proceed to ELBE VOR, holding 3500 feet, report reaching ELBE		
	APP	Report ELBE	cleared for NDB-Approach RWY-05, wind 100, 5 knots, visibility 3 km, RVR 6 km, clouds 2 octa 1000, T=5, DP=3, QNH=1024		
	APP	leaving ELBE	contact HAM TWR on 125.85 when established		
	TWR	1. Kontakt 8	Nr. 1 on final, report reaching OM, QNH 1024		
	TWR	MM	cleared to land		
BMN 27 (2)	RDR	1. Kontakt 8	Descend and maintain 3000, contact APPR on 125.65 reaching BMN-NDB		
	APP	1. Kontakt 8	cleared for holding, descend to 2500		
	APP	Holding	cleared for VOR-Approach RWY 27, QNH 993, contact TWR on 118.3		
	TWR	1. Kontakt 8	cleared to land, wind 210/25, QNH 993		
HAM 23 (3)	DIR	1. Kontakt 8	Descend and maintain 5000, contact APPR 121.25 reaching HTF		
	APP	1. Kontakt 8	Hold above Hamburg VOR, descend and maintain 4000		
	APP	Holding	cleared for ILS-Approach RWY 23, contact Tower reaching OM		
	TWR	1. Kontakt 8	Nr. 1 on final, QNH 1005, report field in sight, wind 180/25-35		
	TWR	Missed Appr.	Follow missed approach procedure, contact Approach on 121.25		
HNV 27 R (4)	DIR	1. Kontakt 8	Descend and maintain 2000, contact APPR reaching 2000, QNH 990		
	APP	1. Kontakt 8	cleared for Holding, maintain 2000		
	APP	Holding	cleared for ILS-Approach RWY 27 R, contact TWR when established		
				leaving Holding	Co-RMI durch Circuit-Breaker ausfallen lassen, durch Drücken des CB wieder Funktion 9
	TWR	1. Kontakt 8	Nr. 2 on final, wind 130/10, QNH 990		
	TWR	MM	cleared to land		
CGN 32 R (5)	DIR	1. Kontakt 8	Descend and maintain 4000		
	DIR	leaving GMH	Report reaching COLA		
	DIR	inbound COLA	cleared for ILS-Approach RWY 32 R, QNH 998, contact Tower when established		
	TWR	establ. on LOC	Nr. 1 on final and cleared to land, wind 290/05		
	TWR	Missed Appr.	contact DIR		

Key: 1-destination airport/runway (test no.) 2-from 3-time 4-instruction 5-content 6-events 7-type 8-contact 9-have Co-RMI fail due to circuit breaker, reinstate by pressing the CB

Table 4.2 (Continued)

Zielflughafen/RWY (Versuch Nr.) 1	Anweisung 4 von 2	Zeit 3	Inhalt 5	Besondere Vorkommnisse 6 Zeit 3	Art 7
DUS 06 (6)	DIR	1. Kontakt 8	Descend and maintain 4000		
	DIR	inbound BOT	cleared for VOR-Approach RWY 06, contact TWR reaching DUS NDB		
	TWR	1. Kontakt 8	Nr. 1 on final, cleared to land, wind calm		
CGN 14 L (7)	DIR	1. Kontakt 8	Descend and maintain 5000, in Holding WYP descend to 3000		
				Inb. WYP	Engine overheat, EGT ↑, N2 ↑
	DIR	Holding	cleared for ILS-Approach RWY 14 L, QNH = 1015, contact TWR when established		
	TWR	1. Kontakt 8	Nr. 1 on final, wind 190/25		
	TWR	MM	cleared to land		
DUS 24 (8)	DIR	1. Kontakt 8	Descend to 3000, Holding BAM, report at BAM		
	DIR	Holding	cleared for NDB Approach RWY 24, QNH 1019, contact TWR on final		
	TWR	1. Kontakt 8	Nr. 2 on final, report at Düsseldorf LI NDB		
				Inbound LI NDB	9 CB ADI vom Capt. ausfallen lassen, nicht zu beheben
	TWR	bei H = 500	cleared to land, wind 260/15		
TOF 27 L (9)	APP	1. Kontakt 8	Descend and maintain 5000		
	APP	inbound TOF	Cleared for VOR/DME-Approach RWY 27 L, descend to 2000, report 2000, QNH 1025, contact TWR reaching TOF VOR		
	TWR	1. Kontakt 8	Nr. 2 on final, report when established (on center line)		
	TWR	on center line	cleared to land, wind calm		
TGL 08 L (10)	APP	1. Kontakt 8	cleared for Holding NIEDER, descend to 2000, QNH 1009		
				Inbound NIEDER	Pitot Icing
	APP	Holding	cleared for ILS-Approach CAT. II RWY 08 L, ATIS Information MIKE: Wind 090/03, QNH 1009, Temp. 5, Dew P. 3, contact Airport 118,70 when established		
	TWR	1. Kontakt 8	cleared to land, wind 090/03, QNH 1009		
TOF 09 R (11)	APP	1. Kontakt 8	descend and maintain 3000, QNH 1004		
	APP	inb. FAHLAND	cleared for DVOR-Approach RWY 09 R, contact TWR 119.10 reaching HVL		
	TWR	1. Kontakt 8	cleared to land, wind 120/05		
TGL 26 L (12)	APP	1. Kontakt 8	descend and maintain 4000, proceed to HVL-VOR, QNH 1003, report HVL		
	APP	inbound HVL	descend to 3000, cleared for ILS-Approach RWY 26 L, contact TWR 119.70 when established		
	TWR	1. Kontakt 8	Nr. 1 on final, cleared to land, wind 190/07		
				on center line	right engine overheat, out
				on center line	ILS-Anzeige (Pilot) ausfallen lassen 10

Key: 1-dest. airport/rwy (test no.) 2-from 3-time 4-instr. 5-content 6-events 7-type 8-contact 9-have Captain cause failure of ADI circuit breaker, do not correct 10-have ILS display (pilot) failure

Table 4.3: List of Crew Activities Determined on the Simulator and their Summary into Task Groups

AUFGABE 1	NR	AUFTRETEN IN PHASE NR. 2	ZUGEHOERIGE EINZELTAETIGKEITEN 3
ATIS 4 ABHOEREN	1	1	CM2: 5 FREQUENZ UND AUDIOKANAL EINSTELLEN; NACHRICHT HOEREN; NOTIZEN MACHEN; AUDIOKANAL ABSCHALTEN
SINKFLUG 7 EINLEITEN	2	1,2,3	CM1: 6 AUTOPILOT AUSSCHALTEN HOEHENRUDER UND TRIMMUNG BETAETIGEN; GAS WEGNEHMEN; VARIOMETER BEOBACHTEN
SINKFLUG 8 BEENDEN	3	1,2,3	CM1: 9 VARIOMETER BEOBACHTEN; HOEHENRUDER UND TRIMMUNG BETAETIGEN; GAS GEBEN; AUTOPILOT EINSCHALTEN
APPROACH CHECK	4	1,2	CM2: 10 CHECKLISTE LAUT LESEN; HOEREN DER ANTWORTEN; SCHALTER BETAETIGEN CM1: REAGIEREN AUF CHECK-LISTE MIT ANTWORTEN UND SCHALTERBETAETIGUNG
FINAL CHECK	5	2,3	CM2: 10 CHECKLISTE LAUT LESEN; HOEREN DER ANTWORTEN; SCHALTER BETAETIGEN CM1: REAGIEREN AUF CHECK-LISTE MIT ANTWORTEN UND SCHALTERBETAETIGUNG
APPROACH BRIEFING	6	1,2	CM1: 11 LESEN UND LAUTES ER-KLAEREN DES ANFLUGES CM2: HOEREN; NOTIZEN MACHEN
"FIELD IN SIGHT"	11	3	CM2: 12 AUFSUCHEN DES SICHTKON-TAKTES ZUR RWY; MELDUNG "FIS" UND UNGEFAEHRE POSITION
LANDEENT- 14 SCHEIDUNG	12	3	CM1: 13 VERGLEICH HOEHE/ENT-SCHEIDUNGS-MINIMUM ENTSCHEIDUNG UND AUSRUF "CONTINUE" BZW. "GO AROUND"

11-read approach flight and explain aloud; listen, make notes
12-seek visual contact with rwy; report "FIS" and approx. position
13-compare alt./decision-minimum; decision and call-out "Continue" or "go around" 14-landing decision

Key: 1-task 2-appears in phase no. 3-attendant single activities 4-listen-in to ATIS 5-set freq. and audiochannel; listen to instr.; make notes; switch off audio. 6-switch off autopilot; operate airelon and trimming; shut off gas; watch variometer 7-begin descent 8-end descent 9-watch variometer; operate elevators and trimming; apply gas; switch on autopilot 10-read checklist aloud; listen to responses; operate switch; react to checklist with responses and switch operation

Table 4.3 (Continued)

AUFGABE 1	NR	AUFTRETEN IN PHASE NR. 2	ZUGEHOERIGE 3 EINZELTAETIGKEITEN
QUERLAGE 4 AENDERN	16	1,2,3	CM1: 5 QUERLAGE BEOBACHTEN; QUERRUDER BETAETIGEN
SPRECH- FUNK 7	25	1,2,3	CM2: 6 SPRECHFUNK DURCHFUEHREN NOTIZEN MACHEN
8 FAHRWERK BETAETIGEN	27	2,3	CM1: 9 KOMMANDO GEBEN; RUECKMELDUNG HOEREN CM2: HEBEL BETAETIGEN; 10 LICHTER BEOBACHTEN; RUECKMELDUNG GEBEN
KLAPPEN 12 BETAETIGEN	28	2,3	CM1: KOMMANDO GEBEN; 9 RUECKMELDUNG HOEREN CM2: HEBEL BETAETIGEN; BEOB- ACHTEN DER NACHFUEHRUNG; RUECKMELDUNG GEBEN 11
KOMMUNI- KATION 13	29	1,2,3	CM1 UND CM2: 14 HOEHREN UND SPRECHEN
GEWICHTE UND GESCHWINDIGKEIT BESTIMMEN 16	30	1,2	CM2: 15 SCHREIBEN UND LESEN

Key: 1-task 2-appears in phase no. 3-attendant single activities 4-change the bank 5-watch bank; operate aileron 6-perform radio speeck; make notes 7-radio speech 8-operate landing gear 9-give command, listen for response 10-operate lever, watch lights, give response 11-operate lever; watch the tracking, give response 12-operate flaps 13-communication 14-listening and speaking 15-writing and reading 16-determine weights and speed.

Table 4.4: List of Non-Task-Specific Measured Quantities from the Test Series run on the Flight Simulator

```
-1-- PHASEN-LAENGE  < DAUER >

-2-- ZEITPUNKT DES UEBERFLUGES   OM                     \
                                                         \    13
-3-- ZEITPUNKT DES ERREICHENS    DH/MINIMUM ALTITUDE      >  BZGL. T/D
                                                         /
-4-- ZEITPUNKT DES AUSRUFES      " FIS      "           /

-5-- ZEITPUNKT DES AUSRUFES      " CONTINUE "           \     13
                                                         >   BZGL. -3--
-6-- ZEITPUNKT DES AUSRUFES      " GO AROUND "          /

-7-- SPANNUNG  U  ALS MASS FUER DIE SICHTBARKEIT
     DES LANDEBAHN-SYMBOLS (KONTINUIERLICH GEMESSEN)

-8-- HEADING

-9-- MILES TO TOUCH DOWN

-10- LOC/GP DEVIATION

-11- ART UND AUFTRITTSZEIT BESONDERER VORKOMMNISSE
     (TRIEBWERKSAUSFALL , NAV.AUSFALL)

-12- ART UND HAEFIGKEIT VON PILOTEN-FEHLERN
     -- FEHLSCHALTUNGEN AM OVERHEAD-PENAL
     -- NICHT KORREKTE DURCHFUEHRUNG DER CHECKLISTEN
     -- FEHLERHAFT DURCHGEFUEHRTE FLUGVERFAHREN
```

Key: 1-phase length (duration) 2-timpoint of overflight OM 3-timepoint of reaching DH/min. alt. 4-timepoint of call-out 5-timepoint of call-out 6-timepoint of call-out 7-voltage U as a measure for the visibility of the runway symbol (measured continually) 8-heading 9-miles to touch down 10-LOC/GP deviation 11-type and timing of special events (engine failure, nav. failure) 12-type and frequence of pilot errors; wrong switch on overhead panel; incorrect execution of checklists; incorrect performance of flight procedures 13-with regard to

Table 4.5: Probability of Occurrance of Once-Only Tasks for the Various Operating Phases (Determined from their frequency of occurrence in the test series)

AUFGABE 1 NR.	NAME	2 AUFTRITTS-WAHRSCHEINLICHKEIT FUER PHASE 1	PHASE 2	PHASE 3
1	ATIS ABHOEREN 3	1.00	0.00	0.00
4	DESCENT CHECK	0.28	0.72	0.00
5	FINAL CHECK	0.00	0.18	0.82
6	APPROACH BRIEFING	0.28	0.72	0.00
27	GEAR DOWN	0.00	0.48	0.52
28	KLAPPEN BETAETIGEN 4	0.00	0.76	0.24
30	LANDING WEIGHT UND APPR. SPEED BESTIMMEN 5	0.53	0.47	0.00

Key: 1-task no. 2-probability of occurrence for
3-listen to ATIC 4-operate flaps
5-determine landing weight and approx. speed.

PROGRAMM 1	FUNKTIONEN 2	3 FUER
LANAM	EINLESEN DER AUFGABEN-NAMEN UND SPEICHERUNG AUF MAGNETPLATTE 4	EINGABE UND UMRECHNUNG AUFGABEN-SPEZIFISCHER DATEN 19
NAMEN	AUSDRUCK UND AENDERUNG DER AUFGABEN-NAMEN 5	
ZZ	EINLESEN, SPEICHERN, AENDERUNG, AUSDRUCK DER ZUORDNUNG VON TAKTMARKEN ZU ECHTZEIT 6	
AUFDAT	EINLESEN DER TAKTMARKEN VON AUFGABENANFANG UND AUFGABENENDE 7	
ORD	UNTERPROGRAMM ZUM ORDEN DER EINGABE-DATEN IN ZEITLICHE REIHENFOLGE 8	
ZB	UNTERPROGRAMM ZUR BERECHNUNG DER ZEITWERTE FUER ANFANGS- UND ENDMARKE, BERECHNUNG VON DAUER UND ZWISCHENZEIT 9	
UMDAT	UMRECHNUNG DER AUFTRITTSZEITEN BZGL. BEGINN DER BETRIEBSPHASE, NORMIERUNG DER AUFTRITTSZEIT AUSGEWAEHLTER AUFGABEN AUF DIE PHASENLAENGE 10	
AUS	TABELLARISCHER AUSDRUCK DER VERSUCHSDATEN 11	
PHADAT	EINLESEN, AUSDRUCK UND SPEICHERN VON BEGINN UND ENDE DER BETRIEBSPHASEN JE VERSUCH, BERECHNUNG DER PHASENDAUER 12	EINGABE UND UMRECHNUNG VON VON EREIGNISS-AUFTRITTSZEITEN 20
ERDAT.	EINLESEN UND SPEICHERUNG DER AUFTRITTSZEITEN VON EREIGNISSEN, POS 2-6 TAB 2.5 13	
HISTA	BERECHNUNG DER HISTOGRAMME VON DAUER UND ZWISCHENZEIT JE AUFGABE UND PHASE 14	HISTORAMM-BERECHNUNG 21
HISTP	BERECHNUNG DER HISTOGRAMME FUER PHASENLAENGE 15	
HISTE	BERECHNUNG DER HISTOGRAMME FUER AUFTRITTSZEITEN DER EREIGNISSE 16	
HZEICH.	ZEICHNEN DER HISTOGRAMME AM X-Y-SCHREIBER 17	
VANP	UNWANDLUNG DER HISTOGRAMME IN VERTEILUNGSDICHTEN, ANPASSUNG EINER MODELL-VERTEILUNGSDICHTE UND PARAMETER-IDENTIFIKATION 18	ANPASSUNG 22

Tab. 4.6: Overview of Programs Developed for...

Key: 1-program 2-functions 3-for 4-read-in task names & storage on disc 5-printout & change of task names 6-read-in, store, revise, printout the allocations of clock marks to real time 7-read-in clock marks from task begin and end 8-subprog. to order input data in chronological sequence 9-subprog. to calc. time values for begin & end marks; calc. duration and interarr. time 10-convert arrival times as per begin of op. phase, norming arr. time of selected tasks to the phase length 11-tabular output of test data 12-read-in, output & store op. phase begin & end per test, calc. phase duration 13-read-in & store arr. times of events 14-calc. histograms of duration and interarr. time per task & phase 15-calc. histog. for phase length 16-calc. histog. for arr. times of events 17-prep. of histog. on X-Y-plotter 18-convert histog. into distr. densities, adapt model distr. density & param. id. 19-input & conversion of task-spec. data 20-input & conv. of event times 21-histog. calc. 22-adaptation

Table 4.7A: Statistical Characteristics for the Processing Time of Tasks in Flight Operations Phase 1 (Initial Approach)

1 AUFGABE NR	1	2	3	4	6	16	25	29	30
2 WERT-ANZAHL	46	132	106	14	16	109	144	108	18
3 MIN MESSWERT	14.3	1.4	1.4	19.3	10.6	1.4	1.8	0.9	14.4
4 MAX MESSWERT	85.1	36.0	38.0	75.4	103.9	38.8	57.2	70.3	65.0
5 EMP MITTELW.	41.8	8.8	11.5	44.2	44.2	16.7	13.1	14.0	35.1
6 EMP VARIANZ	194.6	48.3	92.4	268.0	821.7	235.6	139.6	205.4	278.5
7 MODELLVERT.	NORM	ERL	ERL	NORM	EXP	ERL	ERL	EXP	EXP
8 GESCHAETZTE PARAMETER: P1	38.6	0.1	0.1	39.0	0.02	0.1	0.09	0.05	0.02
P2	131.2	2.0	2.0	636.6	--	2.0	2.0	--	--
5 MITTELWERT	38.8	8.5	9.2	44.0	43.1	7.8	10.9	15.4	34.5
6 VARIANZ	124.8	34.0	40.2	253.0	751.0	33.3	58.8	250.8	239.8

Table 4.7B: Statistical Characteristics for the Interarrival Time of Tasks in Flight Operations Phase 1 (Initial Approach)

Key (to both tables):

1-task no. 2-number of values 3-min. measured value
4-max. measured value 5-average value
6-variance 7-model distribution
8-estimated parameters

1 AUFGABE NR	1	2	3	4	6	16	25	29	30
2 WERT-ANZAHL	46	132	106	14	16	109	144	108	18
3 MIN MESSWERT	0	0	0.09	0	0	0.09	0.01	0.04	0
4 MAX MESSWERT	8.9	6.4	6.5	0.9	0.9	5.9	5.0	4.7	0.9
5 EMP MITTELW.	0.4	1.3	1.3	0.7	0.5	2.1	1.0	1.2	0.5
6 EMP VARIANZ	0.06	2.7	2.3	0.08	0.08	5.2	1.4	1.2	0.08
7 MODELLVERT.	NORM	EXP	EXP	ERL	NORM	EXP	EXP	ERL	NORM
8 GESCHAETZTE PARAMETER: P1	0.3	0.9	1.0	0.2	6.4	0.9	1.0	0.9	0.8
P2	0.09	--	--	3.0	6.0	--	--	2.0	0.5
5 MITTELWERT	0.4	0.9	0.9	0.7	0.5	1.0	0.9	1.0	0.8
6 VARIANZ	0.05	1.1	0.9	0.04	0.08	1.1	0.8	0.5	0.08

Table 4.8A: Statistical Characteristics for the Processing Time of Tasks in Flight Operations Phase 2 (Holding/Approach)

1 AUFGABE NR	2	3	4	5	6	16	25	27	28
2 WERT-ANZAHL	198	206	35	8	41	564	197	20	84
3 MIN MESSWERT	0.7	0.7	0	23.9	8.6	0.1	0.6	0.2	2.9
4 MAX MESSWERT	39.5	110.0	78.4	44.8	199.1	44.2	45.2	17.3	18.2
5 EMP MITTELW.	10.1	13.1	42.5	33.8	111.6	11.7	9.4	5.0	7.7
6 EMP VARIANZ	66.4	348.1	367.8	38.3	6119.0	113.8	48.8	22.9	10.3
7 MODELLVERT.	ERL	EXP	NORM	NORM	NORM	ERL	ERL	NORM	NORM
8 GESCHAETZTE PARAMETER: P1	0.1	0.07	40.4	32.4	51.2	0.1	0.1	2.4	6.8
P2	2	--	151.2	119.1	1498.0	2	2	4.7	7.1
5 MITTELWERT	9.7	12.1	40.4	33.7	58.5	9.7	9.9	2.7	7.0
6 VARIANZ	45.4	109.6	150.4	37.5	1501.0	45.4	49.1	3.4	6.0

Table 4.8B: Statistical Characteristics for the Interarrival Time of Tasks in Flight Operations Phase 2 (Holding/Approach)

Key (to both tables)

1-task no.
2-number of values
3-measured value, min.
4-max. measured value
5-average value
6-variance
7-model distribution
8-estimated parameters

1 AUFGABE NR	2	3	4	5	6	16	25	27	28
2 WERT-ANZAHL	198	206	35	8	41	564	197	20	84
3 MIN MESSWERT	0.01	0	0	0.86	0	0	0	0.81	0.1
4 MAX MESSWERT	14.3	14.5	1.0	0.98	0.76	13.1	6.6	0.98	1.1
5 EMP MITTELW.	0.9	1.0	0.3	0.85	0.15	0.6	1.0	0.84	0.7
6 EMP VARIANZ	5.3	6.0	0.06	0.005	0.03	4.9	1.9	0.005	0.06
7 MODELLVERT.	EXP	EXP	NORM	NORM	NORM	EXP	EXP	NORM	NORM
8 GESCHAETZTE PARAMETER: P1	1.2	1.1	-2.8	0.93	0.01	1.5	0.9	0.86	0.8
P2	--	--	1.2	0.001	0.14	--	--	0.02	0.06
5 MITTELWERT	0.3	0.4	0.3	0.89	0.24	0.2	0.7	0.86	0.7
6 VARIANZ	0.6	0.8	0.06	0.002	0.04	0.3	1.0	0.003	.004

Table 4.9A: Statistical Characteristics for the Execution Time of Tasks in Flight Operations Phase 3 (Final)

1 AUFGABE NR	2	3	5	16	25	27	28	29
2 WERT-ANZAHL	145	155	37	405	69	25	54	109
3 MIN MESSWERT	0.7	0.8	14.4	0.3	2.0	0.9	3.1	0.8
4 MAX MESSWERT	55.2	43.1	83.7	41.1	44.3	13.4	13.4	107.6
5 EMP MITTELW.	14.0	10.0	35.8	8.2	12.4	4.9	8.7	26.7
6 EMP VARIANZ	100.1	80.1	300.6	65.6	98.2	16.7	7.0	1614.6
7 MODELLVERT.	ERL	EXP	NORM	ERL	ERL	EXP	NORM	EXP
8 GESCHAETZTE PARAMETER, P1	0.09	0.07	28.5	0.1	0.09	0.3	9.0	0.08
P2	2	--	160.0	2	2	--	8.4	--
5 MITTELWERT	11.1	11.1	30.6	6.9	10.7	3.4	8.8	9.1
6 VARIANZ	62.1	110.3	118.6	23.6	58.5	6.6	6.3	156.2

Table 4.9B: Statistical Characteristics for the Interarrival Time of tasks in Flight Operations Phase 3 (Final)

Key (to both tables)

1-task no.
2-number of values
3-min. measured value
4-max. measured value
5-average value
6-variance
7-model distribution
8-estimated parameters

1 AUFGABE NR	2	3	5	16	25	27	28	29
2 WERT-ANZAHL	145	155	37	405	69	25	54	109
3 MIN MESSWERT	0	0	0	0	0	0	0	0
4 MAX MESSWERT	2.5	2.9	0.8	2.6	4.2	0.4	1.0	3.2
5 EMP MITTELW.	0.6	0.6	0.3	0.2	0.9	0.2	0.3	1.3
6 EMP VARIANZ	0.3	0.4	0.05	0.1	1.0	0.02	0.06	1.6
7 MODELLVERT.	ERL	NORM	NORM	EXP	NORM	NORM	NORM	EXP
8 GESCHAETZTE PARAMETER, P1	1.6	0.2	0.02	3.3	-0.9	-0.2	0.02	0.7
P2	2	0.2	0.1	--	2.4	0.1	0.2	--
5 MITTELWERT	0.6	0.4	0.2	0.2	0.8	0.1	0.3	1.0
6 VARIANZ	0.2	0.1	0.04	0.09	0.7	0.01	0.06	0.8

Table 4.10: Statistical Characteristics for the Duration of the Flight Operations Phases

1 PHASE NR	1	2	3
2 WERT-ANZAHL	48	48	39
3 MIN MESSWERT	1.5	1.8	1.9
4 MAX MESSWERT	12.9	16.5	5.8
5 EMP MITTELW.	3.9	7.0	3.6
6 EMP VARIANZ	7.3	12.2	0.9
7 MODELLVERT.	NORM	NORM	NORM
8 GESCHAETZTE PARAMETER, P1	-3.1	6.2	3.3
P2	24.0	11.9	1.1
5 MITTELWERT	3.7	6.7	3.4
6 VARIANZ	5.0	9.1	0.8

Key: 1-phase no. 2-no. of values
3-min. measured value
4-max. measured value
5-average value
6-variance
7-model distribution
8-estimated parameters

Table 4.11: Statistical Characteristics for the Timing of Outer Marker (TOM) overflight, of reaching the Decision Alt. (TDH) and of Call-out "Continue" or "Go around" (TE2) and "Field in Sight (TE1). (All timepoints with respect to phase end).

1 ZEITPUNKT	TOM	TDH	TE1	TE2
2 WERT-ANZAHL	47	39	35	24
3 MIN MESSWERT	52.0	28.0	44.0	34.0
4 MAX MESSWERT	130.0	100.0	210.0	97.0
5 EMP MITTELW.	93.4	62.8	98.6	69.3
6 EMP VARIANZ	1020.0	1365.0	9372.0	1482.0
7 MODELLVERT.	NORM	NORM	NORM	NORM
8 GESCHAETZTE PARAMETER: P1	101.3	42.5	70.6	69.2
P2	295.6	2200.	1546.	461.1
5 MITTELWERT	104.9	60.8	83.7	67.6
6 VARIANZ	514.6	501.2	909.9	273.9

Key: 1-timepoint
2-no. of values
3-min. measured value
4-max. measured value
5-average value
6-variance
7-model distribution
8-estimated parameters

Table 4.12: Parameters of the Tasks for Function of the Activity Sequence in the Cockpit

AUFGABE a	PHASE	BEARBEITET VON b	ABHAENGIGKEIT VON c: ANDEREN AUFGABEN d	EREIGNISSEN e	VORRANG VOR ANDEREN AUFGABEN f	MAXIMALE AUFTRITTS-ZAHL g	h BEMERKUNGEN
1 ATIS ABHOEREN i	1 2	PNF	j KEINE	j KEINE	k NEIN	1	
2 SINKFLUG EINLEITEN l	1 2 3	PF	a AUFGABE 25	j KEINE	m ABSOLUTER VORRANG	X	
3 SINKFLUG AUSLEITEN n	1 2 3	PF	j KEINE	j KEINE	m ABSOLUTER VORRANG	X	
4 DESCENT + APPROACH CHECK	1 2	PF + PNF	a AUFGABE 30	j KEINE	k NEIN	1	
5 FINAL CHECK	2	PF + PNF	a AUFGABE 6	j KEINE	k NEIN	1	FINAL CHECK COMPLE *EXCEPT FLAPS + GE
	3	PF + PNF	a AUFGABE 27	OUTER MARKER UEBERFLOGEN o	k NEIN	1	AUFG. 6 IST BEREITS PHASE 2 DURCHGEFUE p
6 APPROACH BRIEFING	1	PF + PNF	AUFGABE a 1	j KEINE	k NEIN	1	
	2	PF + PNF	j KEINE	j KEINE	yes JA	1	AUFG. 1 BEREITS IN PHASE 1 DURCHGEFUE q

Key: a-task
d-other tasks
g-max. no. occurrences
j-none
m-absolute priority
p-task 6....

b-performed by
e-events
h-comments
k-no
n-end descent
q-task 1 executed in phase 1

c-dependent on
f-priority over other tasks
i-listen to ATIS
l-begin descent
o-overflight of OM

Table 4.12 (Continued)

11	"FIELD IN SIGHT"	3	PNF	a KEINE	a KEINE	b JA	1	
12	LANDEENT- SCHEIDUNG e	3	PNF	a KEINE	a KEINE	b JA	1	
16	QUERLAGE AENDERN f	1 2 3	PF	a KEINE	a KEINE	l ABSOLUTER VORRANG	X	
25	SPRECH- FUNK g	1 2 3	PNF	a KEINE	a KEINE	b JA	4 / 6 / 2	
27	FAHRWERK BETAETIGEN h	2 3	PNF	a KEINE	a KEINE	l ABSOLUTER VORRANG	1	
28	KLAPPEN BETAETIGEN i	2 3	PNF	a KEINE	a KEINE	l ABSOLUTER VORRANG	1	
29	KOMMUNI- KATION j	1 2 3	PF + PNF	a KEINE	a KEINE	c NEIN	X	
30	GEWICHT + MAX ANFLUGGESCHW. BESTIMMEN k	1	PNF	d AUFGABE 1	a KEINE	c NEIN	1	
		2	PNF	a KEINE	a KEINE	c NEIN	1	

Key: a-none
d-task 1
g-radio speech
j-communication
l-absolute priority
b-yes
e-landing decision
h-operate land. gear
k-determine weight and max. approach speed
c-no
f-change banking
i-operate flaps

Table 5.1: Program Packet for Computer Simulation and Evaluation of Action Sequences in the Cockpit

HP	UP	1 BESCHREIBUNG	
CINI		3 INITIALISIERUNG DER DATENFILES ZUR SPEICHERUNG DER EINGABEDATEN	2 INITIALISIERUNG UND DATENEINGABE
INIT4		4 INITIALISIERUNG DER DATENFILES ZUR SPEICHERUNG DER SIMULATIONSERGEBNISSE	
CEIN		5 EINLESEN DER EINGABEDATEN FUER CREW	
	CLE	6 LESEN DER DATEN VON PLATTE	
	CSP	7 SCHREIBEN DER DATEN AUF PLATTE	
CREW		8 SIMULATION DES HANDLUNGSABLAUFES IN COCKPIT BEI VARIATION DER PHASENDAUER, AUFGABENDAUER UND -AUFTRITTS- UND EREIGNISZEITEN	18 SIMULATION
	INF	9 ABSPEICHERN DER SIMULATIONS-ERGEBNISSE	
	CQS	10 STEUERUNG DER HANDLUNGSFOLGE	
	STATUA	11 AENDERUNG DER ZUSTANDSGROESSEN BEI AUFTRITT EINER AUFGABE IN DAS CREW-SYSTEM	
	STATUQ	12 AENDERUNG DER ZUSTANDSGROESSEN BEI AUFRUECKEN EINER AUFGABE IN DER SCHLANGE	
	STATUS	AENDERUNG DER ZUSTANDSGROESSEN BEI AUSTRITT EINER AUFGABE AUS DEM CREW-SYSTEM 13	
	UARR	GENERIERUNG DER AUFGABEN- 14 AUFTRITTSZEITEN	
	USER	GENERIERUNG DER AUFGABEN- 15 BEARBEITUNGSDAUER	
	RANDUX	GENERIERUNG DER GLEICHVER- 16 TEILTEN ZUFALLSGROESSE	
	AUS;TEXT	KONTROLLAUSDRUCKE (DATEN, TEXT) 17	

Key: 1-description 2-initialize and data input 3-updating the data file for storage of input data 4-updating the data file for storage of simulation results 5-read-in input data for crew 6-read data from disc 7-write data on disc 8-simulation of action sequence in cockpit for variation of phase duration, task duration and arrival and event times 9-storage of simulation results 10-Control of action sequence 11-change the quantities of state upon arrival of a task in the crew system 12-change quantities of state upon advance of a task in the loop 13-change quantities of state upon exit of a task from the crew system 14-generation of task arrival times 15-generation of task execution time 16-generation of uniform distributed random quantity 17-control printouts (data, text) 18-simulation

Table 5.1 (Continued)

INIT31		INITIALISIERUNG DER DATENFILES ZUR SPEICHERUNG DER HISTOGRAMM-WERTE FUER PHASE 1-3	1	STATISTISCHE AUSWERTUNG 11
SIHIST		BERECHNUG SAEMTLICHER HISTOGRAMME DER VERSUCHSERGEBNISSE AUS CREW UND AESPEICHERUNG DER HISTOGRAMMWERTE FUER JEDE PHASE	2	
	READR	EINLESEN DER SCHON BERECHNETEN HISTOGRAMMWERTE	3	
	ZEITEN	BERECHNUNG DER AUFGABEN-ABHAENGIGEN ZEITEN	4	
	HISTOG	BERECHNUNG DER AUFGABEN-ABHAENGIGEN HISTOGRAMME	5	
	HISTO2	BERECHNUNG DER AUFGABEN-UNABHAENGIGEN HISTOGRAMME	6	
	HISTO3	BERECHNUNG DES HISTOGRAMMS FUER RESTZEIT	7	
	RECORD	ABSPEICHERN DER HISTOGRAMMWERTE VON AUFGABENABHAENGIGEN WERTEN IN DATENFILES	8	
SIZEI		PROGRAMM ZUM ZEICHNEN DER HISTOGRAMME AUF DEM PLOTTER	9	
	ZEICHA	UNTERPROGRAMM ZUR STEUERUNG DES PLOTTERS	10	

Key: 1-updating of data file to store histogram values for phase 1-3
2-calculate all histograms of the test results from crew and store histogram values for each phase
3-read-in histogram values already calculated
4-calculate task-dependent times
5-calculate task-dependent histograms
6-calculate task-independent histograms
7-calculate the histogram for the remaining time
8-store histogram values of task-dependent values in the data file
9-program for drawing the histograms on the plotter
10-subprogram to control the plotter
11-statistical evaluation

NPH	Number of the operating phase
NAT	Number of tasks in operating phase NPH
NZU	Number of important events in the operating phase
	Parameters for Phase Length (Generation of phase length from normal distribution)
XQUER	Average value
VAR	Variance
PMIN	Minimum value
PMAX	Maximum value
	of the phase length
	Task-Related Parameters
I	Item number of tasks in the simulation program
NUM(I)	Id. number of task I from test series on flight simulator
XIX(I) YIY(I)	Base values of the random number generator for generation of execution and interarrival times for task I
AT(I)	Identifier for allocation of tasks to a CM. AT=0 Task I can be executed by CM1 or CM2 AT=1 Task I must be executed by CM1 AT=2 Task I must be executed by CM2 AT=3 Task I must be executed jointly by CM1 and CM2
AAZ(I)	Number of the task on which task I depends
ZAZ(I)	Number of the event on which task I depends
DISZ(I)	Priority of the task simulated by processing discipline in the waiting loop system DISZ=0 First come first served discipline DISZ=1 Last come first served discipline DISZ=2 Absolute priority discipline
ANZ(I)	Maximum number of occurrences for task I in the operating phase (o = no limit on occurrences)
AWA(I)	Probability of occurrence of task I in the operating phase.

Table 5.2: List of Input Parameters for Computer Simulation

Table 5.2 (Continued)

ARR(I)	Identifier for the form of distribution function for interarrival times of task I ARR=0 Exponential distribution ARR=1 Erlang distribution ARR=2 Normal distribution
APA(I)	1st parameter of the distribution for interarrival times
APB(I)	2nd parameter, if any, of the distribution for interarrival times
MIN(I)	Minimum value for interarrival times of task I
MAX(I)	Maximum value for interarrival times of task I
PBZ(I)	Identifier for the phase reference of the task with respect to the interarrival time PBZ=0 No reference PBZ=1 Statement for ZWZ in percent of the phase length
SER(I)	Identifier for the form of distribution function for execution time of task I
SPA(I)	1st parameter of the distribution for execution time
SPB(I)	2nd parameter, if any, of the distribution for execution time
SXQ	Linear average of the execution time
MIN(I)	Minimum value for execution time of task I
MAX(I)	Maximum value for processing time of task I

Table 5.3: Input Parameters of the Computer Simulation for Operating Phase 1

```
*******************************
*                             *
*  CEIN          24-JUN-82    *
*                             *
*******************************
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1 CREW-RECHNERSIMULATION MIT QUEUEING-SYSTEM

2 FUER PHASE NR 1

```
3 GENERATION DER PHASENLAENGE NACH NORMALVERTEILUNGUNG
4 MIT XQUER=   -3.07000    VAR=   24.05990    PMIN=   1.50000    PMAX=   12.94000
  IS,IO,IF,ID,IW:    135    723    387    561    0
  IS,IO,IF,ID,IW:    841    256    669    411    0
  NAT = 14      NZU=   0
```

5 AUFGABENR / 6 PARAMETER	1	2	3	4	5	6	7	8
NUM	1.000	2.000	3.000	4.000	0.000	6.000	16.000	25.000
XIX	127.000	291.000	379.000	419.000	513.000	671.000	739.000	851.000
YIY	135.000	211.000	381.000	443.000	533.000	639.000	795.000	381.000
AT	2.000	1.000	1.000	3.000	0.000	3.000	1.000	2.000
AAZ	0.000	0.000	0.000	14.000	0.000	1.000	0.000	0.000
ZAZ	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ARR	2.000	0.000	0.000	1.000	2.000	2.000	0.000	0.000
PBZ	1.000	0.000	0.000	1.000	1.000	1.000	0.000	0.000
SER	2.000	1.000	1.000	2.000	2.000	0.000	1.000	1.000
DIS	0.000	2.000	2.000	0.000	0.000	0.000	2.000	1.000
APA	0.320	0.930	1.030	0.229	5.000	6.410	0.920	1.030
APB	0.090	0.000	0.000	3.000	0.001	5.970	0.000	0.000
MIN	0.000	0.000	0.090	0.001	4.000	0.001	0.030	0.010
MAX	0.870	6.440	6.490	0.949	6.000	0.910	5.920	4.990
SPA	38.620	0.118	0.108	39.030	0.000	0.017	0.120	0.090
SPB	131.240	2.000	2.000	636.600	0.001	0.000	2.000	2.000
SXQ	38.840	8.450	9.190	43.990	0.000	43.150	7.810	10.950
MIN	14.280	1.440	1.440	19.260	0.000	10.620	1.448	1.690
MAX	85.080	36.000	37.930	75.420	0.001	103.920	33.750	57.240
ANZ	1.000	0.000	0.000	1.000	1.000	1.000	0.000	4.000
AWA	1.000	1.000	1.000	0.280	0.000	0.280	1.000	1.000

5 AUFGABENR / 6 PARAMETER	9	10	11	12	13	14	15	16
NUM	0.000	0.000	0.000	0.000	29.000	30.000		
XIX	973.000	913.000	953.000	871.000	714.000	602.000		
YIY	989.000	965.000	917.000	831.000	754.000	698.000		
AT	0.000	0.000	0.000	0.000	3.000	2.000		
AAZ	0.000	0.000	0.000	0.000	0.000	1.000		
ZAZ	0.000	0.000	0.000	0.000	0.000	0.000		
ARR	2.000	2.000	2.000	2.000	1.000	2.000		
PBZ	1.000	1.000	1.000	1.000	0.000	1.000		
SER	2.000	2.000	2.000	2.000	0.000	0.000		
DIS	0.000	0.000	0.000	0.000	0.000	0.000		
APA	5.000	5.000	5.000	5.000	0.980	0.830		
APB	0.001	0.001	0.001	0.001	2.000	0.460		
MIN	4.000	4.000	4.000	4.000	0.040	0.000		
MAX	6.000	6.000	6.000	6.000	4.670	0.940		
SPA	0.000	0.000	0.000	0.000	0.052	0.020		
SPB	0.001	0.001	0.001	0.001	0.000	0.000		
SXQ	0.000	0.000	0.000	0.000	15.420	34.470		
MIN	0.000	0.000	0.000	0.000	0.960	14.400		
MAX	0.001	0.001	0.001	0.001	70.320	65.040		
ANZ	1.000	1.000	1.000	1.000	0.000	1.000		
AWA	0.000	0.000	0.000	0.000	1.000	0.530		

TZU 999.000

Key: 1-crew computer simulation with queueing system
2-for phase no. 1
3-generation of phase length from normal distribution
4-with
5-task no.
6-parameter

Table 5.4: Results of the Computer Simulation from Test Series 1

8 VERSUCHSREIHE NR. 1 PHASE NR. 1 9 ANZAHL DER VERSUCHE: 2000

10 AUFG. NR.	PARAMETER	NGES	XMIN	XMAX	XQUER	SIGMQ
1	AUFTRITTSZEIT 1	1904	0.00	240.00	70.15	442.47
1	BEARBEITUNGSBEGINN 2	1732	0.00	240.00	82.40	1141.11
1	BEARBEITUNGSENDE 3	1549	0.00	240.00	127.23	1224.93
1	WARTEZEIT 4	760	0.00	240.00	23.93	833.60
1	BEARBEITUNGSDAUER 5	1549	14.20	85.00	46.19	427.35
1	RESTZEIT 6	355	14.20	85.00	36.95	29.84
1	ZWISCHENZEIT 7	0	0.00	0.00	0.00	0.00
2	AUFTRITTSZEIT	5273	0.00	240.00	101.61	4293.53
2	BEARBEITUNGSBEGINN	5273	0.00	240.00	101.61	4293.53
2	BEARBEITUNGSENDE	4753	0.00	240.00	107.21	4027.71
2	WARTEZEIT	1254	0.00	240.00	5.51	96.35
2	BEARBEITUNGSDAUER	4753	1.44	36.00	7.96	33.89
2	RESTZEIT	520	1.44	36.00	9.37	60.40
2	ZWISCHENZEIT	3651	0.00	386.40	37.39	1593.35
3	AUFTRITTSZEIT	6024	0.00	240.00	104.38	4051.18
3	BEARBEITUNGSBEGINN	6024	0.00	240.00	104.38	4051.19
3	BEARBEITUNGSENDE	5420	0.00	240.00	110.40	3741.33
3	WARTEZEIT	1401	0.00	240.00	5.45	98.75
3	BEARBEITUNGSDAUER	5420	1.44	37.99	8.36	36.38
3	RESTZEIT	604	1.44	37.98	8.97	62.80
3	ZWISCHENZEIT	4364	5.40	389.40	35.30	1164.35
4	AUFTRITTSZEIT	438	0.00	240.00	148.05	2185.49
4	BEARBEITUNGSBEGINN	62	0.00	240.00	197.74	598.45
4	BEARBEITUNGSENDE	8	0.00	240.00	207.50	293.75
4	WARTEZEIT	95	0.00	240.00	37.37	1676.23
4	BEARBEITUNGSDAUER	8	19.26	75.42	36.23	110.54
4	RESTZEIT	422	19.26	75.42	42.21	17.98
4	ZWISCHENZEIT	0	0.00	0.00	0.00	0.00
6	AUFTRITTSZEIT	483	0.00	240.00	96.71	3652.31
6	BEARBEITUNGSBEGINN	384	0.00	240.00	157.01	1433.47
6	BEARBEITUNGSENDE	133	0.00	240.00	183.81	1210.59
6	WARTEZEIT	685	0.00	240.00	35.22	2163.13
6	BEARBEITUNGSDAUER	133	10.62	103.92	29.44	318.81
6	RESTZEIT	358	10.62	103.92	38.49	138.02
6	ZWISCHENZEIT	0	0.00	0.00	0.00	0.00
7	AUFTRITTSZEIT	5758	0.00	240.00	102.35	4379.79
7	BEARBEITUNGSBEGINN	5758	0.00	240.00	102.35	4379.79
7	BEARBEITUNGSENDE	5184	0.00	240.00	187.94	4095.57
7	WARTEZEIT	1393	0.00	240.00	5.67	88.30
7	BEARBEITUNGSDAUER	5184	1.44	33.76	7.90	33.59
7	RESTZEIT	566	1.44	33.76	7.71	41.37
7	ZWISCHENZEIT	4115	1.80	355.20	36.76	1405.46
8	AUFTRITTSZEIT	5914	0.00	240.00	89.75	3791.52
8	BEARBEITUNGSBEGINN	4796	0.00	240.00	94.45	4312.98
8	BEARBEITUNGSENDE	4494	0.00	240.00	182.01	4048.51
8	WARTEZEIT	2645	0.00	240.00	17.57	386.64
8	BEARBEITUNGSDAUER	4494	1.80	57.24	10.21	56.88
8	RESTZEIT	1420	1.80	57.24	8.72	3.81
8	ZWISCHENZEIT	4167	0.60	299.40	36.86	1332.45
13	AUFTRITTSZEIT	6121	0.00	240.00	109.45	3964.87
13	BEARBEITUNGSBEGINN	3795	0.00	240.00	110.71	4683.27
13	BEARBEITUNGSENDE	2981	0.00	240.00	120.52	3952.73
13	WARTEZEIT	4945	0.00	240.00	16.69	680.78
13	BEARBEITUNGSDAUER	2981	0.96	70.32	13.74	164.24
13	RESTZEIT	3148	0.96	70.32	14.93	22.10
13	ZWISCHENZEIT	4377	2.40	280.20	44.27	1037.33
14	AUFTRITTSZEIT	832	0.00	240.00	121.07	3097.65
14	BEARBEITUNGSBEGINN	553	0.00	240.00	160.85	1357.14
14	BEARBEITUNGSENDE	396	0.00	240.00	181.64	923.32
14	WARTEZEIT	439	0.00	240.00	48.52	1916.26
14	BEARBEITUNGSDAUER	396	14.40	65.04	31.04	182.13
14	RESTZEIT	436	14.40	65.04	32.46	24.40
14	ZWISCHENZEIT	0	0.00	0.00	0.00	0.00

Key: 1-arrival time 2-beginning of execution 3-end of execution 4-waiting time 5-execution time 6-remaining time 7-inter-arrival time 8-test series no. 9-number of tests 10-task no.

Table 5.5: Frequency of Pilot Overloads in the Computer Simulation (test series 1)

	1 Überlastung durch Aufgabe 8	1 Überlastung durch Aufgabe 13	Überlastung durch 1 Aufgabe 1	1 Überlastung durch Aufgabe 4
	(mehrfaches Auftreten) 2		(nicht bis zum Sollzeitpunkt erledigt) 3	
4 Versuchsreihe 1	12.6 %	31.3 %	22.6 %	7.5 %

Key: 1-overload due to task 2-repeated occurrence 3-not completed by the spec. time
4-test series

PROGRAMS

Key: 1-simulation of the work sequence in the cockpit 2-option to repeat an already-simulated approach 3-repeat a simulation run? 4-of test no. 5-from file no. 6-heatline output and read-in the control parameters 7-test series no.

```
C         ***************************************************
C         HP CREW   , 1 SIMULATION DES ARBEITSABLAUFES IM COCKPIT
C         ***************************************************
C
C         LINKBLOCK
C         CREW=CREW/F/C
C         KOPF,CKRIT,UUB/O:1/C
C         COS,EMOD,STATUA,STATUQ,STATUS/O:1/C
C         UARR,USER,AUS,INF,RANDUX

          DIMENSION IAUF(20),AN(20),ANZ(20)

          COMMON/A/ASTAT(20,10),XKZ(20),ZSTAT(20),TZU(20),TREST(20)
          COMMON/AA/AT(20),DISZ(20),ANZX(20),XNUM(20)
          COMMON/B/SCH1(10),SCH2(10),QLEN1,QLEN2,SYSN1,SYSN2,SYSN
          COMMON/C/AAZ(20),APA(20),APB(20),APR(20),ZAZ(20),AO(20),AU(20)
          COMMON/D/SER(20),SPA(20),SPB(20),XIX(20),YIY(20),
          1TIM(4),TNEXT,TLAST,SO(20),SU(20)
          COMMON/E/ZEIT(20),RAUF(20)
          COMMON/F/XA,XB,XLAST,UBL(20)
          COMMON/G/TIN(200),S1(200),S2(200),S3(200),S4(200),S5(200),INAN
          COMMON/H/XNAT(20),A(20),B(20),TN(20),PBZ(20),AUA(20)
          COMMON/HH/TOM,TDH,USI,USF,XGA,E1,E2,TE1,TE2,TFCH,TACH,TABR

          DOUBLE PRECISION PRNAM,Z0,Z1,Z2,Z3,Z4,ZE1,ZE2,XKR(60)
          DATA PRNAM /8HCREW     /
          DATA STRI  /4H----/
          DATA Z0 /8HNEUTRAL /
          DATA Z1 /8HF.I.S.   /
          DATA Z2 /8HCONTINUE/
          DATA Z3 /8HGO AROUN/
          DATA Z4 /8HKEINE    /
          DATA XKR /60*8H--------/
          DATA XKR(1),XKR(2) /8HATIS     ,8HFUNK     /
          DATA XKR(21),XKR(22) /8HA-CHECK ,8HA-BRIEF /
          DATA XKR(23),XKR(24) /8HNO A-BR ,8HFUNK     /
          DATA XKR(25) /8HNO V/G-B/
          DATA XKR(41),XKR(42) /8HE2 LOW  ,8HFI-CHECK/
          DATA XKR(43),XKR(44) /8HFUNK    ,8HGEAR     /
          DATA XKR(45),XKR(46) /8HFLAPS   ,8HKEINE E2/
          DATA XKR(47) /8HFREIGABE/

          DEFINE FILE 4 (100,2400,U,IUAR)
          READ(4'1)TIN,S1,S2,S3,S4,S5
C       2 OPTION AUF WIEDERHOLUNG EINES BEREITS SIMULIERTEN ANFLUGES
C         **********************************************************
          KWDH=0
          WRITE(7,3997)                                  3
3997      FORMAT(1H$,'  WIEDERHOLUNG EINES SIMULATIONSLAUFES ? ')
          READ(5,13)KWDH
          IF(KWDH.NE.1)GOTO 3998
          WRITE(7,3999)               4
3999      FORMAT(1H$,'  WDH VON VERSUCH NR ')
          READ(5,13)NRW
          WRITE(7,4000)                  5
4000      FORMAT(1H$,'              AUS FILE NR ')
          READ(5,13)NFW
13        FORMAT(I3)
          DEFINE FILE NFW(100,2400,U,IVAR)

C       6 KOPF-AUSDRUCK UND EINLESEN DER STEUERPARAMETER
C         ********************************************
3998      CALL KOPF(PRNAM,7)
          WRITE(7,2000)
2000      FORMAT(1H$,'  PHASE NR ')
          READ(5,3000)NPH
3000      FORMAT(I3)
          WRITE(7,1999)               7
1999      FORMAT(1H$,'  VERSUCHSREIHE NR ')
          READ(5,2999)VREI
2999      FORMAT(F20.10)
```

Key: 1-read-in the input parameters form magnetic disc
     2-updating the remaining parameters

```
C       1EINLESEN DER EINGABEPARAMETER VON MAGNETPLATTE
C        ***********************************************
         NF1=NPH
         DEFINE FILE NF1(42,40,U,IVAR)
         DO 808 I=1,10
         READ(NF1'I)A
         DO 809 J=1,20
809      ASTAT(J,I)=A(J)
808      CONTINUE
         READ(NF1'11)XNAT
         READ(NF1'12)XIX
         READ(NF1'13)AT
         READ(NF1'14)AAZ
         READ(NF1'15)ARR
         READ(NF1'16)SER
         READ(NF1'17)DISZ
         READ(NF1'18)APA
         READ(NF1'19)APB
         READ(NF1'20)SPA
         READ(NF1'21)SPB
         READ(NF1'22)ANZX
         READ(NF1'23)XKZ
         READ(NF1'24)SCH1,SCH2
         READ(NF1'25)IS1,IS2,IO1,IO2,IF1,IF2,ID1,ID2,IW1,IW2
         READ(NF1'26)ZEIT
         READ(NF1'27)RAUF
         READ(NF1'28)B
         READ(NF1'29)TN
         READ(NF1'30)AWA
         READ(NF1'31)ZAZ
         READ(NF1'32)ZSTAT
         READ(NF1'33)TZU
         READ(NF1'34)YIY
         READ(NF1'35)AU
         READ(NF1'36)AO
         READ(NF1'37)SU
         READ(NF1'38)SO
         READ(NF1'39)PBZ
         READ(NF1'40)NPH,IP1,IP2,PXQ,PVAR,PMIN,PMAX
         READ(NF1'42)XNUM
C       2INITIALISIERUNG DER RESTLICHEN PARAMETER
C        ****************************************
         TEND=0.
         INAN=0
         KFORT=0
         NAT=IFIX(XNAT(1))
         NZU=IFIX(XNAT(2))

         IF(KUDH.NE.1)GOTO 4003
         READ(NFW'NRW)TIN,S1,S2,S3,S4,S5
         DO 4001 J=1,20
4001     XIX(J)=S3(J)
         DO 4002 J=21,40
4002     YIY(J-20)=S3(J)
         IW1=IFIX(S3(85))
         IW2=IFIX(S3(86))

4003     DO 4 J=1,200
         TIN(J)=0.
         S1(J)=0.
         S2(J)=0.
         S3(J)=0.
         S4(J)=0.
         S5(J)=0.
4        CONTINUE

         DO 1 J=1,20
         AN(J)=0.
         TREST(J)=0.
1        CONTINUE

         DO 2 J=1,4
         TIM(J)=10.**30.
2        CONTINUE
```

Key: 1-output of control params. 2-crew comp. simulation with queueing system 3-OM flyover 4-param. ref. to time 5-variation of param. except 6-run the simulation 7-no. of sim. runs 8-control output 9-phase duration 10-variable phase duration 11-fixed phase duration 12-visibility, OM, DH for phase 13-variable visibility 14-fixed visibility

```
C       1AUSGABE DER STEUERPARAMETER
C        ***************************
114      CALL KOPF(PRNAM,6)
         PRINT 327,VREI,NPH,NAT,NZU                       2
327      FORMAT(3X,'CREW-RECHNERSIMULATION MIT QUEUEING-SYSTEM',
        1//,3X,'VERSUCHSREIHE ',F5.2,/,
        13X,'FUER PHASE NR ',I2,//,3X,'NAT=',I4,4X,'NZU=',I4)
         IF(NPH.EQ.3)PRINT 223                          3
223      FORMAT(3X,'ZUSTAND NR 1 = OUTER MARKER UEBERFLOGEN',/,      Task-decision stage
        13X,'AUFGABE   11 = ENTSCHEIDUNG STUFE 1 -- F.I.S.',/,
        13X,'               -PARAMETER-BEZUG AUF PHASEN-ENDE',/,
        13X,'AUFGABE   12 = ENTSCHEIDUNG STUFE 2 -- CONT/GA',/,
        13X,'               -PARAMETER-BEZUG AUF ZEIT/DH',/)
251      FORMAT(3X,'VARIATION DER PARAMETER AUSSER:')  4
                                                 5
C       6DURCHFUEHRUNG DER SIMULATION
C        ****************************
         XA=0.
         XB=0.

         WRITE(7,340)              7
340      FORMAT(3X,'ANZAHL SIMULATIONSLAEUFE(MAX.100):',/,3X,
        1$,'NSIM=')
         READ(5,13)NSIM

         WRITE(7,341)              8
341      FORMAT(1H$,'  KONTROLL-AUSDRUCK ?  JA=2 :')
         READ(5,13)KON
         IF(KON.EQ.0)GOTO 335
         XA=KON*1.
         XB=KON*1.

C       9PHASENDAUER:
335      IF(KUDH.NE.1)GOTO 336
         IPVAR=0
         GOTO 4004
336      WRITE(7,400)              10
400      FORMAT(1H$,'  VARIABLE PHASENDAUER ? ')
         READ(5,13)IPVAR
         IF(IPVAR.EQ.1)GOTO 401
4004     WRITE(7,402)                 11
402      FORMAT(1H$,'  FESTE PHASENDAUER IN SEC= ')
         READ(5,403)DAUER
403      FORMAT(F20.10)
         PRINT 4010,DAUER             11
4010     FORMAT(3X,'FESTE DAUER = ',F8.2,' SEC')

C      12SICHT,OM,DH FUER PHASE 3:
401      IF(NPH.NE.3)GOTO 220
         IF(KUDH.NE.1)GOTO 200
         ISVAR=0
         GOTO 202
200      WRITE(7,201)              13
201      FORMAT(1H$,'  VARIABLE SICHT BEI DH ? ')
         READ(5,13)ISVAR
         IF(ISVAR.EQ.1)GOTO 204
202      WRITE(7,203)                   14
203      FORMAT(1H$,'  FESTE SICHT BEI DH IN VOLT= ')
         READ(5,403)USI
         PRINT 4011,USI            14
4011     FORMAT(3X,'FESTE SICHT BEI DH =',F8.2,' VOLT')

204      IF(KUDH.NE.1)GOTO 205
         IFVAR=0
         GOTO 207
205      WRITE(7,206)              13
206      FORMAT(1H$,'  VARIABLE SICHT BEI F.I.S. ?')
         READ(5,13)IFVAR
         IF(IFVAR.EQ.1)GOTO 209
207      WRITE(7,208)                   14
208      FORMAT(1H$,'  FESTE SICHT BEI F.I.S. IN VOLT =')
         READ(5,403)USF
         PRINT 4012,USF
4012     FORMAT(3X,'FESTE SICHT BEI F.I.S. =',F8.2,' VOLT')
                                   14
```

Key: 1-variable timepoint for 2-fixed timepoint for 3-potential for test output during simulation 4-detailed LP-output for test 5-calculation of phase duration 6-generation from normal distribution 7-duration

```
209     IF(KUDH.NE.1)GOTO 210
        IOVAR=0
        GOTO 212
210     WRITE(7,211)                              1
211     FORMAT(1H$,'  VARIABLER ZEITPUNKT FUER OM ?')
        READ(5,13)IOVAR
        IF(IOVAR.EQ.1)GOTO 214
212     WRITE(7,213)                         2
213     FORMAT(1H$,'  FESTER ZEITPUNKT FUER OM IN SEC:  TOM=')
        READ(5,403)TOM
        PRINT 4008,TOM                 2
4008    FORMAT(3X,'FESTER ZEITPUNKT OM =',F8.2,' SEC')

214     IF(KUDH.NE.1)GOTO 215
        IDVAR=0
        GOTO 217
215     WRITE(7,216)                      1
216     FORMAT(1H$,'  VARIABLER ZEITPUNKT FUER DH ?')
        READ(5,13)IDVAR
        IF(IDVAR.EQ.1)GOTO 219
217     WRITE(7,218)                    2
218     FORMAT(1H$,'  FESTER ZEITPUNKT FUER DH IN SEC:  TDH=')
        READ(5,403)TDH
        PRINT 4009,TDH               2
4009    FORMAT(3X,'FESTER ZEITPUNKT DH =',F8.2,' SEC')

219     GOTO 2200
220     USI=10.
        USF=10.
        TOM=0.
        TDH=0.
        ISVAR=0
        IOVAR=0
        IDVAR=0
        IFVAR=0
2200    CONTINUE

        IF(KUDH.NE.1)GOTO 4005
        WRITE(7,349)NRW,NFW
        PRINT 349,NRW,NFW
4005    WRITE(7,350)
        PRINT 350

        IF(KUDH.NE.1)GOTO 4006
        LREC=NRW
        GOTO 4007

C       ********************
4006    DO 1000 LREC=1,NSIM
C       ********************

C     3 MOEGLICHKEIT FUER TESTAUSDRUCK WAEHREND SIMULATION
        IF(KOM.NE.2)GOTO 777
        WRITE(7,778)LREC
778     FORMAT(1H$,'  AUSFUEHRLICHER LP-AUSDRUCK FUER VERSUCH 4',
        1I2,' ?')
        READ(5,779)KOM2
779     FORMAT(I3)
        XA=2.
        XB=2.
        IF(KOM2.EQ.0)XA=0.
        IF(KOM2.EQ.0)XB=0.
777     CONTINUE

C     5 BERECHNUNG DER PHASENDAUER
4007    IF(IPVAR.NE.1)GOTO 404
C     6 GENERATION NACH NORMALVERTEILUNG:
330     P=COS(2.*3.14159*RAN(IP1,IP2))
        Q=(-2.*PVAR*ALOG(RAN(IP1,IP2)))**0.5
      7 DAUER=PXQ+P*Q
        IF(DAUER.LT.PMIN)GOTO 330
        IF(DAUER.GT.PMAX)GOTO 330
      7 DAUER=DAUER*60.
404     CONTINUE
```

Key: 1-print-out of results 2-determination of tasks which occurred in the sim. run in spite of having an occurrence prob. less than one 3-determination of print-out on landing decision 4-determination of tasks remaining in the server 5-print-out for various conditions 6-first possibility: System is overloaded 7-second possibility: simulation end, the system is empty 8-third possibility: Simulation end, remaining tasks in the system 9-fourth possibility: termination due to "go around"

```
C       1 AUSDRUCK DER ERGEBNISSE
C         ***********************
C       2 ERMITTLUNG DER AUFGABEN, DIE IM SIM.LAUF TROTZ EINER
C         AUFTRITTS-WAHRSCHEINLICHKEIT < 1 AUFGETRETEN SIND:
          DO 362 J=1,20
362       IAUF(J)=0
          IANZ=0
          DO 361 J=1,20
          IF(AVA(J).EQ.1.)GOTO 361
          IF(XKZ(J).EQ.0.)GOTO 361
          IANZ=IANZ+1
          IAUF(IANZ)=J
361       CONTINUE
          PRINT 2006,(STRI,J=1,20)
2006      FORMAT(T2,20A4)
C       3 BESTIMMUNG DES AUSDRUCKES UEBER LANDE-ENTSCHEIDUNG
          IF(NPH.EQ.3)GOTO 369
          ZE1=Z4
          ZE2=Z4
          GOTO 380
369       ZE1=Z0
          IF(E1.EQ.1.)ZE1=Z1
          ZE2=Z2
          IF(E2.EQ.3.)ZE2=Z3
380       CONTINUE
C       4 BESTIMMUNG DER REST-AUFGABEN IM SERVER
          NS1=0
          NS2=0
          DO 363 J=1,20
          IF(ASTAT(J,1).EQ.6.8)NS1=J
          IF(ASTAT(J,1).EQ.6.8)NS2=J
363       CONTINUE
          DO 360 J=1,20
          IF((ASTAT(J,1).EQ.3.).OR.(ASTAT(J,1).EQ.8.))NS1=J
          IF((ASTAT(J,1).EQ.4.).OR.(ASTAT(J,1).EQ.8.))NS2=J
360       CONTINUE
          IF(QLEN1.EQ.SYSN1)NS1=0
          IF(QLEN2.EQ.SYSN2)NS2=0
C       5 AUSDRUCK FUER VERSCHIEDENE KONDITIONEN:
C         --------------------------------------
          IF(XGA.EQ.1.)GOTO 335
C       6-1.MOEGL.:  SYSTEM IST UEBERLASTET
          IF(XLAST.EQ.0.) GOTO 332
          WRITE (7,351) LREC,DAUER,TEND
          PRINT 351,LREC,DAUER,TEND,XLAST,(IAUF(K),K=1,IANZ)
C         WRITE(7,352)(SCH1(11-K),K=1,10),NS1,(SCH2(11-K),K=1,10),NS2
C         PRINT 352,(SCH1(11-K),K=1,10),NS1,(SCH2(11-K),K=1,10),NS2
          GOTO 999
C       7-2.MOEGL.:  SIM-ENDE, DAS SYSTEM IST LEER
332       IF(SYSN.NE.0)GOTO 334
          WRITE(7,354)LREC,DAUER,TEND
          PRINT 354,LREC,DAUER,TEND,(IAUF(K),K=1,IANZ)
          GOTO 999
C       8-3.MOEGL.:  SIM-ENDE, REST AUFGABEN IM SYSTEM
334       WRITE(7,353)LREC,DAUER,TEND
          PRINT 353,LREC,DAUER,TEND,(IAUF(K),K=1,IANZ)
C         WRITE(7,352)(SCH1(11-K),K=1,10),NS1,(SCH2(11-K),K=1,10),NS2
C         PRINT 352,(SCH1(11-K),K=1,10),NS1,(SCH2(11-K),K=1,10),NS2
          GOTO 999
C       9-4.MOEGL.: ABBRUCH WEGEN GO AROUND
          WRITE(7,356)LREC,DAUER,TE2
          PRINT 356,LREC,DAUER,TE2
```

Key: 1-calculation of visibility at decision altitude
2-calculation of visibility at F.I.S.
3-Calculation of timpoint for OM overflight
4-calculation of timepoint to reach DH
5-updating the determined results
6-print-out at beginning of approach
7-simulation of activity sequence

```
C       1 BRECHNUNG DER SICHT BEI ENTSCHEIDUNGSHOEHE
          IF(ISVAR.NE.1)GOTO 225
C         GENERATION NACH EXP.-VERT.
C         MIT LAMBDA=0.4103,  MIN=0., MAX=10.
226       P=ALOG(1.-RAN(IS1,IS2))
          USI=-P/0.4103
          IF((USI.LT.0.).OR.(USI.GT.10.))GOTO 226
          USI=10.-USI
225       CONTINUE
C       2 BERECHNUNG DER SICHT BEI F.I.S.
          IF(IFVAR.NE.1)GOTO 227
C         GENERATION NACH GLEICH-VERT.
C         MIT A=0.7482  B=9.4185  MIN=0.   MAX=10.
228       USF=0.4782+8.6703*RAN(IF1,IF2)
          IF((USF.LT.0.).OR.(USF.GT.10.))GOTO 228
          USF=10.-USF
227       CONTINUE
C       3 BERECHNUNG DES ZEITPUNKTES FUER UEBERFLIEGEN OM
          IF(IOVAR.EQ.0)TOM=DAUER-TOM
          IF(IOVAR.NE.1)GOTO 229
C         GENERATION NACH NORMAL-VERT.
C         MIT XM=101.3  VAR=295.6  MIN=52.0  MAX=130.0
230       P=COS(2.*3.14159*RAN(IO1,IO2))
          Q=(-2.*295.6*ALOG(RAN(IO1,IO2)))**0.5
          TOM=101.3+P*Q
          IF((TOM.LT.52.).OR.(TOM.GT.130.))GOTO 230
          TOM=DAUER-TOM
          IF(TOM.LT.0.)GOTO 230
229       IF(NPH.EQ.3)NZU=1
          IF(NPH.EQ.3)TZU(1)=TOM
C       4 BERECHNUNG DES ZEITPUNKTES VON ERREICHEN DH
          IF(IDVAR.EQ.0)TDH=DAUER-TDH
          IF(IDVAR.NE.1)GOTO 231
C         GENERATION NACH NORMAL-VERT.
C         MIT XM=42.5   VAR=2200.   MIN=28.   MAX=100.
232       P=COS(2.*3.14159*RAN(ID1,ID2))
          Q=(-2.*2200.*ALOG(RAN(ID1,ID2)))**0.5
          TDH=42.5+P*Q
          IF((TDH.LT.28.).OR.(TDH.GT.100.))GOTO 232
          TDH=DAUER-TDH
          IF(TDH.LT.0.)GOTO 232
231       CONTINUE
C       5 INITIALISIERUNG DER ENTSCH.ERGEBNISSE
          XGA=0.
          E1=0.
          E2=0.
          TE1=DAUER
          TE2=DAUER
C       6 AUSDRUCK BEI BEGINN DES ANFLUGES
          WRITE(7,967)LREC,DAUER
967       FORMAT(T2,I3,T15,F6.1)
C       7 SIMULATION DES TAETIGKEITSABLAUFS
C         **********************************
          CALL COS(NAT,NZU,DAUER,LREC,TEND,VREI,
         1NPH,KWA,IW1,IW2)
          WRITE(4'LREC)TIN,S1,S2,S3,S4,S5
```

Key: 1-repeat test no. 13 from file 2-results of computer simulation 3-seek critical events and print-out 4-supplemental print-out of frequency 5-end of entire computer simulation 6-continue the simulation 7-end output on special events in the computer simulation 8-crew overload

```
999     IF(NPH.NE.3)GOTO 998
C       WRITE(7,355)TOM,TDH,USF,USI
C       PRINT 355,TOM,TDH,USF,USI
C       WRITE(7,357)TE1,ZE1,TE2,ZE2
C       PRINT 357,TE1,ZE1,TE2,ZE2
998     CONTINUE

349   1 FORMAT(3X,'WIEDERHOLUNG DES VERSUCHES NR ',I3,' AUS FILE ',I2)
350   2 FORMAT(T20,'ERGEBNISSE DER RECHNERSIMULATION',/,
        1T20,'********************************',//,
        1T2,'LFD-NR',T15,' DAUER',T22,'  SIM.ABBRUCH BEI',/,
        1T15,' [SEC]',T22,'T[SEC]',T30,'KONDITION')
351     FORMAT(T2,I3,T15,F6.1,T22,F6.1,T30,'CREW UEBERLASTET ',
        1'DURCH AUFGABE ',F4.0,
        1/,T2,X,T30,'AUFTRITT BEI AWA(1 VON: ',10I3)
352     FORMAT(T30,10F4.0,'/',I2,'/',/,T30,10F4.0,'/',I2,'/')
353     FORMAT(T2,I3,T15,F6.1,T22,F6.1,T30,'PHASENENDE',/,T2,X,
        1T30,'AUFTRITT BEI AWA(1 VON: ',10I3,/,T2,X,T30,'RESTL.AUFGABEN:')
354     FORMAT(T2,I3,T15,F6.1,T22,F6.1,T30,'SIM.-ENDE',/,T2,X,
        1T30,'AUFTRITT BEI AWA(1 VON: ',10I3)
355     FORMAT(T2,X,T30,'TOM=',F6.2,3X,'TDH=',F6.2,3X,'USF=',F5.1,
        13X,'USI=',F5.1)
356     FORMAT(T2,I3,T15,F6.1,T22,F6.1,T30,'ABBRUCH WEGEN GO AROUND')
357     FORMAT(T2,X,T30,'T=',F6.1,' ENTSCH-1:',A8,/,
        1T2,X,T30,'T=',F6.1,' ENTSCH-2:',A8)

C     3 AUFSUCHEN KRITISCHER EREIGNISSE UND AUSDRUCK
C       ------------------------------------------
        CALL CKRIT(NAT,NPH,DAUER)

C     4 ZUSATZAUSDRUCK UEBER AUFG.HAEUFIGKEIT
C       ---------------------------------
C       PRINT 371,(J,J=1,20)
371     FORMAT(T2,'AUFG.NR.',20I3)
C       PRINT 372,(XKZ(J),J=1,20)
372     FORMAT(T2,'ANZAHL  :',20F3.0)
        DO 358 J=1,20
358     IAUF(J)=0
        DO 359 J=1,20
359     IF(ASTAT(J,1).EQ.5.)IAUF(J)=1
C       PRINT 370,(IAUF(J),J=1,20)
370     FORMAT(T2,'FERTIG :',20I3)

C       ********
1000    CONTINUE
C       ********

C     5 ENDE DER GESAMTEN RECHNER-SIMULATION
C       ----------------------------------
        IF(KWDH.EQ.1)GOTO 2005
        WRITE(7,2004)                       6
2004    FORMAT(1H$,'  FORTSETZUNG DER SIMULATION ? ')
        READ(5,13)KFORT
        IF(KFORT.NE.1)GOTO 2005
        NF1=NPH
        READ(NF1'1)XNUM
        WRITE(NF1'12)XIX
        WRITE(NF1'25)IS1,IS2,IO1,IO2,IF1,IF2,ID1,ID2,IW1,IW2
        WRITE(NF1'34)YIY
        WRITE(NF1'40)NPH,IP1,IP2,PXQ,PVAR,PMIN,PMAX

C     7 ENDAUSDRUCK UEBER BESONDERE VORKOMMNISSE IN RECHNER-SIM.
C       -----------------------------------------------------
        PRINT 7000,VREI,NPH
7000    FORMAT(///,3X,'BESONDERE VORKOMMNISSE IN VERSUCHSREIHE ',
        1F4.1,/,3X,'VON PHASE',I3,' :',/,3X,'--------------------',
        1-------------------------------------------')
        PRINT 7001
7001  8 FORMAT(3X,'UEBERLASTUNG DER CREW :')
        DO 7003 J=101,120
        JJ=J-100
        IF(S3(J).GT.0.)PRINT 7002,JJ,S3(J)
7002    FORMAT(3X,'DURCH AUFGABE',I3,' IN ',F4.0,' % DER ANFLUEGE')
7003    CONTINUE
```

Key: 1-seek crew errors in computer simulation 2-breakdown by phase 3-check for crew errors in phase one 4-check for crew errors in phase two

```
      LAD=0
      IF(NPH.EQ.2)LAD=20
      IF(NPH.EQ.3)LAD=40
      PRINT 7004
7004  FORMAT(//,3X,'CREW-FEHLER :')

      DO 7006 J=121,140
      JJ=J-120
      IF(S3(J).GT.0.)PRINT 7005,XKR(LAD+JJ),S3(J)
7005  FORMAT(3X,'FEHLER "',A8,'" IN ',F4.0,' % DER ANFLUEGE')
7006  CONTINUE

      STOP
      END


C     ******************************************************
C   1 UP CKRIT ,  SUCHE NACH CREW-FEHLERN BEI RECHNERSIMULATION
C     ******************************************************

      SUBROUTINE CKRIT(NAT,NPH,DAUER)
C     ------------------------------
      COMMON/A/ASTAT(20,10),XKZ(20),ZSTAT(20),TZU(20),TREST(20)
      COMMON/HH/TOM,TDH,USI,USF,XGA,E1,E2,TE1,TE2,TFCH,TABR
      COMMON/G/TIN(200),S1(200),S2(200),S3(200),S4(200),S5(200),INAN
      DIMENSION IFE(10)

      DO 1 J=1,10
1     IFE(J)=0

C   2 AUFTEILUNG NACH PHASE:
C     *********************
      GOTO(100,200,300)NPH

C   3 UEBERPRUEFUNG AUF CREW-FEHLER FUER PHASE 1
C     ******************************************
100   IF(ASTAT(1,1).EQ.5.)GOTO 102
      S3(121)=S3(121)+1.
      IFE(1)=1
D     PRINT 101
101   FORMAT(T2,'CREW-FEHLER:',T30,'ATIS NICHT/UNVOLLST.BEARBEITET')
102   IF(XKZ(7).GT.0.)GOTO 104
      S3(122)=S3(122)+1.
      IFE(2)=2
D     PRINT 103
103   FORMAT(T2,'CREW-FEHLER:',T30,'KEIN ATC-KONTAKT')
104   CONTINUE
      GOTO 999

C   4 UEBERPRUEFUNG AUF CREW-FEHLER FUER PHASE 2
C     ******************************************
200   DHALB=DAUER/2.
      IF(TACH.LE.DHALB)GOTO 202
      S3(121)=S3(121)+1.
      IFE(1)=1
D     PRINT 201
201   FORMAT(T2,'CREW-FEHLER:',T30,'APPROACH CHECK ZU SPAET')

202   IF(TABR.LE.DHALB)GOTO 204
      S3(122)=S3(122)+1.
      IFE(2)=2
D     PRINT 203
203   FORMAT(T2,'CREW-FEHLER:',T30,'APP.BRIEF. ZU SPAET')

204   IF(ASTAT(6,1).EQ.5.)GOTO 206
      S3(123)=S3(123)+1.
      IFE(3)=3
D     PRINT 205
205   FORMAT(T2,'CREW-FEHLER:',T30,'APP.BRIEF. NICHT ERFOLGT')
```

```
206     IF(XKZ(8).GE.2.)GOTO 208
        S3(124)=S3(124)+1.
        IFE(4)=4
D       PRINT 207
207     FORMAT(T2,'CREW-FEHLER:',T30,'KEINE FREIGABE')

208     IF(ASTAT(14,1).EQ.5.)GOTO 999
        S3(125)=S3(125)+1.
        IFE(5)=5
D       PRINT 209
209     FORMAT(T2,'CREW-FEHLER:',T30,'GEW.+GESCHW. NICHT BERECHNET')
        GOTO 999

C       UEBERPRUEFUNG AUF CREW-FEHLER FUER PHASE 3
C       ******************************************
300     IF(TE2.LE.TDH)GOTO 3011
        S3(121)=S3(121)+1.
        IFE(1)=1
D       PRINT 301
301     FORMAT(T2,'CREW-FEHLER:',T30,'LANDE-ENTSCHEIDUNG UNTERHALB DH')

3011    IF(TFCH.LT.DAUER)GOTO 3021
        S3(122)=S3(122)+1.
        IFE(2)=2
D       PRINT 302
302     FORMAT(T2,'CREW-FEHLER:',T30,'FINAL CHECK NOT COMPLETED')

3021    IF(XKZ(8).GE.1.)GOTO 3022
        S3(123)=S3(123)+1.
        IFE(3)=3
D       PRINT 103

3022    IF(ASTAT(9,1).EQ.5.)GOTO 3031
        S3(124)=S3(124)+1.
        IFE(4)=4
D       PRINT 303
303     FORMAT(T2,'CREW-FEHLER:',T30,'GEAR NOT DOWN')

3031    IF(ASTAT(10,1).EQ.5.)GOTO 3041
        S3(125)=S3(125)+1.
        IFE(5)=5
D       PRINT 304
304     FORMAT(T2,'CREW-FEHLER:',T30,'FLAPS NOT SET')

3041    IF(TE2.LT.DAUER)GOTO 3051
        S3(126)=S3(126)+1.
        IFE(6)=6
D       PRINT 305
305     FORMAT(T2,'CREW-FEHLER:',T30,'LANDEENTSCHEIDUNG NICHT ERFOLGT')

3051    IF(ASTAT(8,1).EQ.5.)GOTO 999
        S3(127)=S3(127)+1.
        IFE(7)=7
D       PRINT 306
306     FORMAT(T2,'CREW-FEHLER:',T30,'LANDUNG OHNE FREIGABE')

999     PRINT 1000,(IFE(J),J=1,10)
1000    FORMAT(T2,'CREW-FEHLER:',T30,10I3)

        RETURN
        END
```

Key: 1-check for crew errors in phase three 2-no approval 3-weight and speed not calculated 4-landing decision below DH 5-landing decision not made 6-landing without approval

```
C       ************************************************************
C       UP CQS  , ABLAUF-STEUERUNG DER WARTESCHLANGEN-SIMULATION 1
C       ************************************************************

        SUBROUTINE CQS(MAT,NZU,DAUER,LREC,TEND,VREI,
        1NPH,KWA,IW1,IW2)
C       ------------------------------------------
        COMMON/A/ASTAT(20,10),XKZ(20),ZSTAT(20),TZU(20),TREST(20)
        COMMON/AA/AT(20),DISZ(20),ANZX(20),XNUM(20)
        COMMON/B/SCH1(10),SCH2(10),QLEN1,QLEN2,SYSN1,SYSN2,SYSN
        COMMON/D/SER(20),SPA(20),SPB(20),XIX(20),YIY(20),
        1TIM(4),TNEXT,TLAST,SO(20),SU(20)
        COMMON/E/ZEIT(20),RAUF(20)
        COMMON/F/XA,XB,XLAST,UBL(20)
        COMMON/G/TIN(200),S1(200),S2(200),S3(200),S4(200),S5(200),INAN
        COMMON/HH/TOM,TDH,USI,USF,XGA,E1,E2,TE1,TE2,TFCH,TACH,TABR

        KA=IFIX(XA)
        KB=IFIX(XB)

C     3 *** ES WIRD ANGENOMMEN, DASS DAS SYSTEM ZU BEGINN DER
C       *** SIMULATION LEER IST

C     2 INITIALISIERUNG DER ZUSTANDSGROESSEN
C       **********************************
        DO 303 J=1,20
        DO 302 K=1,10
302     ASTAT(J,K)=0.
303     CONTINUE

        DO 304 J=1,200
        TIN(J)=0.
        S1(J)=0.
        S2(J)=0.
        S4(J)=0.
304     S5(J)=0.
        DO 300 J=1,20
300     S3(J)=XIX(J)
        DO 301 J=21,40
301     S3(J)=YIY(J-20)
        S3(43)=VREI
        S3(85)=IW1*1.
        S3(86)=IW2*1.
        DO 305 J=44,63
305     S3(J)=XNUM(J-43)

        NS1=0
        NS2=0
        DO 60 J=1,20
        ZSTAT(J)=0.
        TREST(J)=0.
        XKZ(J)=0.
        ZEIT(J)=0.
        RAUF(J)=0.
60      CONTINUE
        DO 61 J=1,10
        SCH1(J)=0.
61      SCH2(J)=0.

        TIM(3)=0.
        SYSNT=0.
        QLEN1=0.
        QLEN2=0.
        TSYS=0.
        TQUEU1=0.
        TQUEU2=0.
        SYSN=0.
        SYSN1=0.
        SYSN2=0.
        TNEXT=0.
        INAN=0
        TLAST=0.
        XLAST=0.
        TFCH=DAUER 4
        TACH=DAUER 4
        TABR=DAUER 4
```

Key: 1-sequence control of waiting-loop simulation 2-updating of quantities of state
3-it is assumed that the system is empty at the beginning of the simulation
4-duration

Key: 1-determination of the first arrival time
2-determination of the next event
3-service routine channel one

```
C      1 ERMITTLUNG DES ERSTEN ANKUNFTSZEIT
C        ********************************
         TIM(1)=10.**30.
         TIM(2)=10.**30.
         TIM(4)=DAUER
         NXA=0

         CALL UARR(NAT,TIM(3),NXA,NPH,DAUER,KWA,IW1,IW2)
         TNEXT=TIM(3)
         IF(NZU.EQ.0)GOTO 200
         DO 200 J=1,NZU
         IF(TNEXT.GE.TZU(J))ZSTAT(J)=1.
200      CONTINUE
         GOTO 30

C      2 ERMITTLUNG DES HAECHSTEN EREIGNISSES
C        **********************************
2        TLAST=TNEXT
         NEXT=1
         TNEXT=TIM(1)

         DO 3 I=2,4
         IF(TNEXT.LE.TIM(I))GOTO 3
         TNEXT=TIM(I)
         NEXT=I
3        CONTINUE
         TEND=TNEXT
         IF(NEXT.GT.2)GOTO 800
         IF((TIM(1).EQ.TIM(2)).AND.(TIM(1).NE.10.**30.))NEXT=5
800      CONTINUE

         IF(NZU.EQ.0)GOTO 201
         DO 201 J=1,NZU
         IF(TNEXT.GE.TZU(J))ZSTAT(J)=1.
201      CONTINUE

         IF(KA.EQ.2)WRITE(6,400)(TIM(L),L=1,4),NEXT
         IF(KA.EQ.2)WRITE(7,400)(TIM(L),L=1,4),NEXT
400      FORMAT(3X,'TIM=',4(2XE10.4),2X,'NEXT=',I2)

         GOTO(10,20,30,40,70) NEXT

C        *****************************************************

C      3 SERVICE - ROUTINE  KANAL  1
C        **************************
10       IF(KA.EQ.2)PRINT 700
700      FORMAT(3X,'SERVICE IN KANAL 1,')
         NS1=0
         DO 11 J=1,20
11       IF((ASTAT(J,1).EQ.3.).OR.(ASTAT(J,1).EQ.8.))NS1=J
         SYSN=SYSN-1.
         SYSN1=SYSN1-1.
         CALL STATUS(NS1,NPH,DAUER)
         TIM(1)=10.**30.
         IF(E2.NE.3.)GOTO 500
         XGA=1.
         GOTO 40

500      CALL INF(LREC,0)
         IF(QLEN1.GT.0.)GOTO 5
         GOTO 2

5        NQ1=IFIX(SCH1(1))
         CALL STATUQ(1,NQ1,NS1,NS2,NABS)
         CALL INF(LREC,0)

         IF(NS1.EQ.0)GOTO 2
         IF(NABS.NE.1)CALL USER(NAT,NS1,TIM(1))
         GOTO 2

C        *****************************************************
```

Key: 1-service routine channel two 2-service routine for both channels simultaneously

```
C       1SERVICE - ROUTINE  KANAL  2
C        ***************************
20       IF(KA.EQ.2)PRINT 701
701      FORMAT(3X,'SERVICE IN KANAL 2.')
         NS2=0
         DO 21 J=1,20
21       IF((ASTAT(J,1).EQ.4.).OR.(ASTAT(J,1).EQ.8.))NS2=J
         SYSN=SYSN-1.
         SYSN2=SYSN2-1.
         CALL STATUS(NS2,NPH,DAUER)
         TIM(2)=10.**30.
         IF(E2.NE.3.)GOTO 501
         XGA=1.
         GOTO 40

501      CALL INF(LREC,0)
         IF(QLEN2.GT.0.)GOTO 6
         GOTO 2

6        NQ2=IFIX(SCH2(1))
         CALL STATUQ(2,NQ2,NS1,NS2,NABS)
         CALL INF(LREC,0)

         IF(NS2.EQ.0)GOTO 2
         IF(NABS.NE.1)CALL USER(NAT,NS2,TIM(2))
         GOTO 2

C        *********************************************************

C       2SERVICE-ROUTINE FUER BEIDE KANAELE GLEICHZEITIG
C        ***********************************************
70       IF(KA.EQ.2)PRINT 702
702      FORMAT(3X,'SERVICE IN KANAL 1+2.')

         DO 71 J=1,20
71       IF(ASTAT(J,1).EQ.8.)NS=J
         SYSN=SYSN-1.
         SYSN1=SYSN1-1.
         SYSN2=SYSN2-1.
         CALL STATUS(NS,NPH,DAUER)
         TIM(1)=10.**30.
         TIM(2)=10.**30.
         IF(E2.NE.3.)GOTO 502
         XGA=1.
         GOTO 40

502      CALL INF(LREC,0)
         IF((QLEN1.EQ.0.).AND.(QLEN2.GT.0.))NFALL=1
         IF((QLEN1.GT.0.).AND.(QLEN2.EQ.0.))NFALL=2
         IF((QLEN1.EQ.0.).AND.(QLEN2.EQ.0.))NFALL=3
         IF((QLEN1.GT.0.).AND.(QLEN2.GT.0.))NFALL=4
         GOTO(72,73,74,75)NFALL

72       TIM(1)=10.**30.
         NQ2=IFIX(SCH2(1))
         CALL STATUQ(2,NQ2,0,NS2,NABS)
         CALL INF(LREC,0)
         IF(NS2.EQ.0)GOTO 2
         IF(NABS.NE.1)CALL USER(NAT,NS2,TIM(2))
         GOTO 2

73       TIM(2)=10.**30.
         NQ1=IFIX(SCH1(1))
         CALL STATUQ(1,NQ1,NS1,0,NABS)
         CALL INF(LREC,0)
         IF(NS1.EQ.0)GOTO 2
         IF(NABS.NE.1)CALL USER(NAT,NS1,TIM(1))
         GOTO 2

74       TIM(1)=10.**30.
         TIM(2)=10.**30.
         GOTO 2
```

Key: 1-arrival routine 2-determination whether unit is moving
     up for processing 3-advance of unit for execution

```
75      NQ1=IFIX(SCH1(1))
        NQ2=IFIX(SCH2(1))
        IF((DISZ(NQ1).GT.0.).OR.(DISZ(NQ2).GT.0.))GOTO 100
        NSL=1
        GOTO 103
C       - - - - - - - - - - - - - - - - - -
100     IF(DISZ(NQ1).GT.0.)NSL=1
        IF(DISZ(NQ2).GT.0.)NSL=2
        GOTO(103,102)NSL
C       - - - - - - - - - - - - - - - - - -
103     CALL STATUQ(1,NQ1,NS1,NS2,NABS1)
        IF(NS1.GT.0)GOTO 104
105     GOTO(102,106)NSL
C       - - - - - - - - - - - - - - - - - -
104     IF(NABS1.EQ.1)GOTO 105
        CALL USER(NAT,NS1,TIM(1))
        IF(NS1.NE.NS2)GOTO 105
        TIM(2)=TIM(1)
        GOTO 106
C       - - - - - - - - - - - - - - - - - -
102     CALL STATUQ(2,NQ2,NS1,NS2,NABS2)
        IF(NS2.GT.0)GOTO 101
107     GOTO(106,103)NSL
C       - - - - - - - - - - - - - - - - - -
101     IF(NABS2.EQ.1)GOTO 107
        CALL USER(NAT,NS2,TIM(2))
        IF(NS1.NE.NS2)GOTO 107
        TIM(1)=TIM(2)
C       - - - - - - - - - - - - - - - - - -
106     CALL INF(LREC,0)
        GOTO 2

C       ***********************************************************

C      1ANKUNFTS - ROUTINE
C       ******************
30      IF(KA.EQ.2)PRINT 703
703     FORMAT(3X,'ANKUNFT:')

        CALL STATUA(NAT,NXA)
        CALL INF(LREC,NXA)
        IF(DISZ(NXA).EQ.2.)CALL INF(LREC,0)
        IF(XLAST.NE.0.)GOTO 40

C      2ERMITTLUNG, OB EINHEIT GLEICH ZUR BEARBEITUNG AUFRUECKT
C       -------------------------------------------------------
        IF(AT(NXA).NE.1.)GOTO 53
        IF((QLEN1.EQ.SYSN1).AND.(SYSN1.NE.0.))GOTO 50
53      IF(AT(NXA).NE.2.)GOTO 54
        IF((QLEN2.EQ.SYSN2).AND.(SYSN2.NE.0.))GOTO 51
54      IF(AT(NXA).NE.3.)GOTO 55
        IF((QLEN1.NE.SYSN1).OR.(QLEN2.NE.SYSN2))GOTO 55
        IF((SYSN1.EQ.0.).OR.(SYSN2.EQ.0.))GOTO 55
        GOTO 50
55      GOTO 52
50      CONTINUE

C      3AUFRUECKEN DER EINHEIT ZUR BEARBEITUNG
C       -------------------------------------
        NQ1=IFIX(SCH1(1))
        NS1=NXA
        CALL UARR(NAT,TIM(3),NXA,NPH,DAUER,KUA,IU1,IU2)
        GOTO 5

51      NQ2=IFIX(SCH2(1))
        NS2=NXA
        CALL UARR(NAT,TIM(3),NXA,NPH,DAUER,KUA,IU1,IU2)
        GOTO 6

52      CALL UARR(NAT,TIM(3),NXA,NPH,DAUER,KUA,IU1,IU2)
        GOTO 2

C       ***********************************************************
```

Key: 1-end of simulation 2-collection of data on task profile for output file

```
C       1ENDE DER SIMULATION
C        *******************
40       CONTINUE
         TEND=TLAST
         IF((TIM(1).LT.10.**30.).OR.(TIM(2).LT.10.**30.))TEND=TNEXT
         IF(INAN.GT.200) GOTO 995
         S3(41)=INAN*1.
         S3(42)=TEND
         S3(50)=DAUER
         S3(51)=TOM
         S3(52)=TDH
         S3(53)=USI
         S3(54)=USF
         S3(55)=XGA
         S3(56)=E1
         S3(57)=E2
         S3(58)=TE1
         S3(59)=TE2
         DO 600 J=61,70
600      S3(J)=SCH1(J-60)
         DO 601 J=71,80
601      S3(J)=SCH2(J-70)
         DO 602 J=1,20
         IF((ASTAT(J,1).EQ.3.).OR.(ASTAT(J,1).EQ.8.))S3(81)=J*1.
602      IF((ASTAT(J,1).EQ.4.).OR.(ASTAT(J,1).EQ.8.))S3(82)=J*1.
         DAU=DAUER
         IF(XLAST.NE.0.)DAU=TEND
         IF(S3(81).GT.0.)S3(83)=TIM(1)-DAU
         IF(S3(82).GT.0.)S3(84)=TIM(2)-DAU
995      CONTINUE

         RETURN
         END


C       2 *****************************************************************
C         UP INF ,SAMMLUNG DER DATEN UEBER AUFGABENVERLAUF FUER AUSGABE-FILE
C         *****************************************************************

          SUBROUTINE INF(LREC,NARR)
C         ------------------------
          COMMON/A/ASTAT(20,10),XKZ(20),ZSTAT(20),TZU(20),TREST(20)
          COMMON/B/SCH1(10),SCH2(10),QLEN1,QLEN2,SYSN1,SYSN2,SYSN
          COMMON/D/SER(20),SPA(20),SPB(20),XIX(20),YIY(20),
          1TIM(4),TNEXT,TLAST,SO(20),SU(20)
          COMMON/G/TIN(200),S1(200),S2(200),S3(200),S4(200),S5(200),INAN
          S3(41)=200.
          S3(42)=TNEXT
          INAN=INAN+1
          IF(INAN.LT.200)GOTO 2
          IF(INAN.GT.200)GOTO 999
          PRINT 1,TNEXT
1         FORMAT(3X,'TNEXT=',F8.2,'  AB HIER KEINE AUFZEICHNUNG DES,
          1ABLAUFES')
          GOTO 999
2         TIN(INAN)=TNEXT
          NS1=0
          NS2=0
          DO 5 J=1,20
          IF(ASTAT(J,1).EQ.6.0)NS1=J
          IF(ASTAT(J,1).EQ.6.0)NS2=J
5         CONTINUE
          DO 3 J=1,20
          IF((ASTAT(J,1).EQ.3.).OR.(ASTAT(J,1).EQ.8.)) NS1=J
          IF((ASTAT(J,1).EQ.4.).OR.(ASTAT(J,1).EQ.8.)) NS2=J
3         CONTINUE
```

Key: 1-positioning of an occurring data in the system
2-determination of task type 3-if task can only be executed in KN2; 4-with FCFS discipline

```
      IF(QLEN1.EQ.SYSN1)NS1=0
      IF(QLEN2.EQ.SYSN2)NS2=0
      S1(INAN)=NS1*1.
      S2(INAN)=NS2*1.
      S4(INAN)=0.
      S5(INAN)=0.
6     IF(NARR.EQ.0)GOTO 999
      A=FLOAT(NARR)
      DO 7 J=1,10
7     IF(ASTAT(NARR,J).EQ.0.)GOTO 8
8     J=J-1
      IF(ASTAT(NARR,J).EQ.7.)S4(INAN)=A
      IF(ASTAT(NARR,J).EQ.7.)S5(INAN)=A
      IF((ASTAT(NARR,J).EQ.1.).OR.(ASTAT(NARR,J).EQ.3.))S4(INAN)=A
      IF((ASTAT(NARR,J).EQ.2.).OR.(ASTAT(NARR,J).EQ.4.))S5(INAN)=A
999   CONTINUE
      RETURN
      END

C      ************************************************************
C   1  UP STATUA, POSITIONIERUNG EINER AUFTRETENDEN AUFGABE IM SYSTEM
C      ************************************************************

      SUBROUTINE STATUA(NAT,NXA)
C     ------------------------
      COMMON/A/ASTAT(20,10),XKZ(20),ZSTAT(20),TZU(20),TREST(20)
      COMMON/AA/AT(20),DISZ(20),ANZX(20),XNUM(20)
      COMMON/B/SCH1(10),SCH2(10),QLEN1,QLEN2,SYSN1,SYSN2,SYSN
      COMMON/D/SER(20),SPA(20),SPB(20),XIX(20),YIY(20),
     1TIM(4),TNEXT,TLAST,SO(20),SU(20)
      COMMON/F/XA,XB,XLAST,UBL(20)
      COMMON/G/TIN(200),S1(200),S2(200),S3(200),S4(200),S5(200),INAN
      KA=IFIX(XA)
      KB=IFIX(XB)
      XKZ(NXA)=XKZ(NXA)+1.
      NUBL=IFIX(UBL(NXA))
C     NAX=NUMMER DER AUFGABE,DIE GERADE ERSCHIENEN IST.
C     STATUS=1,2   : AUFGABE IN SCHLANGE 1 BZW 2
C     STATUS=3,4   : AUFGABE IN SERVER   1 BZW 2
C     STATUS=5     : AUFGABE IST ABGEARBEITET
C     STATUS=6     : AUFGABE ZURUECKGESTELLT (DURCH ABS.PROIR.-AUFG)
C     STATUS=6.8   : GEMEINSAME AUFGABE, BEI EINEM CM ZURUECKGESTELLT
C     STATUS=6.9   : GEMEINSAME AUFGABE, BEI BEIDEN CM'S ZURUECKGESTELLT
C     STATUS=7     : AUFGABE IN SCHLANGE 1 UND 2 GLEICHZ.
C     STATUS=8     : AUFGABE IN SERVER   1 UND 2 GLEICHZ.

C   2 ERMITTLUNG DES AUFGABENTYPS
C     **************************
      IF(AT(NXA).EQ.0.) GOTO 10
      IF(AT(NXA).EQ.1.) GOTO 11
      IF(AT(NXA).EQ.2.) GOTO 12
      IF(AT(NXA).EQ.3.) GOTO 800

C   3 WENN AUFGABE NUR IN KN2 ABGEFERTIGT WERDEN KANN!
C     ***********************************************
12    KSCH=2
      IF(DISZ(NXA).EQ.1.) GOTO 20
      IF(DISZ(NXA).EQ.2.) GOTO 200

C   4 MIT FCFS-DISZIPLIN :
C     -----------------
      DO 21 J=1,10
21    IF(SCH2(J).EQ.0.) GOTO 22
      GOTO 950
22    SCH2(J)=NXA*1.
      IF(J.EQ.1.) QLEN2=0.
      SYSN2=SYSN2+1.
      QLEN2=QLEN2+1.
      SYSN=SYSN+1.
      SYSNT=SYSNT+1.
      DO 60 J=1,10
      IF(ASTAT(NXA,J).EQ.0.)GOTO 61
60    CONTINUE
```

Key: 1-with LCFS discipline 2-absolute priority 3-determine content of server two 4-elements of loop one are set back one place 5-content of server two is set back to the 1st place of loop 2 6-set the status of the reset single task 7-set the status of the reset, joint task and service time from KN1 temporarily to infinity 8-priority task NXA is set into server 2

```
61        ASTAT(NXA,J)=2.
          IF(ASTAT(NXA,NUBL).EQ.0.)GOTO 13
62        WRITE(7,600)NXA,NXA,NUBL,(ASTAT(NXA,J),J=1,NUBL)
          IF(KA.EQ.2)PRINT 600,NXA,NXA,NUBL,(ASTAT(NXA,J),J=1,NUBL)
600       FORMAT(3X,'***SYSTEM IST MIT AUFG. ',I2,' UEBERLASTET ***',
          1/,3X,'*** ASTAT(',I2,',1...',I2,')= ',10F6.0,' ***')
          XLAST=FLOAT(NXA)
          S3(100+NXA)=S3(100+NXA)+1.
          GOTO 13
C       1 MIT LCFS-DISZIPLIN :
C         -------------------
20        DO 23 J=1,10
23        IF(SCH2(J).EQ.0.) GOTO 24
          GOTO 950
24        IF(J.EQ.1.) QLEN2=0.
          IF(J.EQ.1.) GOTO 25
26        SCH2(J)=SCH2(J-1)
          J=J-1
          IF(J.GT.1.) GOTO 26
25        SCH2(1)=NXA*1.
          SYSN2=SYSN2+1.
          SYSN=SYSN+1.
          SYSNT=SYSNT+1.
          QLEN2=QLEN2+1.
          DO 64 J=1,10
          IF(ASTAT(NXA,J).EQ.0.)GOTO 65
64        CONTINUE
65        ASTAT(NXA,J)=2.
          IF(ASTAT(NXA,NUBL).NE.0.)GOTO 62
          GOTO 13
C       2 ABSOLUTE PRIORITAET:
C         -------------------
200       CONTINUE
C       3 BESTIMMUNG DES INHALTES VON SERVER 2
201       NS2=0
          DO 2010 J=1,20
2010      IF(ASTAT(J,1).EQ.6.8)NS2=J
          DO 202 J=1,20
202       IF((ASTAT(J,1).EQ.4.).OR.(ASTAT(J,1).EQ.8.))NS2=J
C         SERVER 2 LEER ?
          IF(NS2.EQ.0)GOTO 210
C       4 ELEMENTE DER SCHLANGE 1 WERDEN UM EINEN PLATZ ZURUECK-
C         GESETZT:
          DO 203 J=1,10
203       IF(SCH2(J).EQ.0.)GOTO 204
          GOTO 950
204       IF(J.EQ.1)GOTO 2042
2041      SCH2(J)=SCH2(J-1)
          J=J-1
          IF(J.GE.2)GOTO 2041
C       5 INHALT DES SERVER 2 WIRD AUF DEN 1.PLATZ DER SCHLANGE 2
C         ZURUCKGESETZT:
2042      SCH2(1)=NS2*1.
          IF(ASTAT(NS2,J).NE.6.8)TREST(NS2)=TIM(2)-TNEXT
          QLEN2=QLEN2+1.
          IF(ASTAT(NS2,1).NE.6.8)GOTO 2011
          ASTAT(NS2,1)=6.9
          GOTO 210
2011      IF(ASTAT(NS2,1).EQ.8.)GOTO 221
C       6 SETZEN DES STATUS DER ZURUECKGESETZTEN EINZEL-AUFGABE:
          ASTAT(NS2,1)=6.
          GOTO 210
C       7 SETZEN DES STATUS DER ZURUECKGESETZTEN GEMEINSAMEN AUFGABE,
C         SOWIE SERVICE-ZEIT VON KN1 VORUEBERGEHEND AUF UNENDLICH:
221       ASTAT(NS2,1)=6.8
          TIM(1)=10.**20.
C       8 VORRANGIGE AUFGABE NXA WIRD IN DEN SERVER 2 GESETZT:
210       SYSN2=SYSN2+1.
          SYSN=SYSN+1.
          SYSNT=SYSNT+1.
          CALL USER(NAT,NXA,TIM(2))
          TM=TIM(2)
```

Key: 1-check whether task NXA is already present in thesystem
2-seek the second NXA in the loop 3-cancel move back the remaining loop 4-if task can only be executed in channel one 5-with FCFS discipline 6-with LCFS discipline

```
C      1 PRUEFEN,OB AUFGABE NXA BEREITS IM SYSTEM
C        VORHANDEN,ALSO ASTAT(NXA,1)=6.  (WEGEN DISZ=2.)
         IF(ASTAT(NXA,1).NE.6.)GOTO 501
C        NXA BEREITS VORHANDEN UND ZURUECKGESTELLT:
C        BEAUFSCHLAGUNG DER SERVICE-DAUER VON NXA UM TREST
         TR=TREST(NXA)
         TIM(2)=TIM(2)+TREST(NXA)
         TREST(NXA)=0.
C      2 AUFSUCHEN DER DOPPELTEN NXA IN DER SCHLANGE
C      3 LOESCHEN UND NACHRUECKEN DER RESTL. SCHLANGE
         DO 502 J=1,9
         IF(SCH2(J).NE.(NXA*1.))GOTO 502
         DO 503 K=J,9
503      SCH2(K)=SCH2(K+1)
         GOTO 504
502      CONTINUE
504      IF(SCH2(10).EQ.(NXA*1.))SCH2(10)=0.
         QLEN2=QLEN2-1.
         SYSN2=SYSN2-1.
         SYSN=SYSN-1.
         SYSNT=SYSNT-1.
         IF(KA.EQ.2)PRINT 910,NXA,TM,TR,TIM(2)
910      FORMAT(3X,'***DOPPELTES AUFTRETEN DER ABS.PRIOR.AUFG.',I3,':',
        13X,'***URSPRUENGLICH VORGESEHENES TIM(2): ',F8.2,/,
        13X,'***BEAUFSCHLAGUNG DURCH TREST        : ',F8.2,/,
        13X,'***RESULTIERENDES TIM(2)             : ',F8.2)
501      ASTAT(NXA,1)=4.
         GOTO 13

C      4 WENN AUFGABE NUR IN KANAL 1 ABGEFERTIGT WERDEN KANN
C        ************************************************
11       KSCH=1
         IF(DISZ(NXA).EQ.1.) GOTO 30
         IF(DISZ(NXA).EQ.2.) GOTO 250

C      5 MIT FCFS-DISZIPLIN :
C        -------------------
         DO 31 J=1,10
31       IF(SCH1(J).EQ.0.) GOTO 32
         GOTO 950
32       SCH1(J)=NXA*1.
         IF(J.EQ.1.) QLEN1=0.
         SYSN1=SYSN1+1.
         QLEN1=QLEN1+1.
         SYSN=SYSN+1.
         SYSNT=SYSNT+1.
         DO 66 J=1,10
         IF(ASTAT(NXA,J).EQ.0.)GOTO 67
66       CONTINUE
67       ASTAT(NXA,J)=1.
         IF(ASTAT(NXA,NUBL).NE.0.) GOTO 62
C        WRITE(7,904)(SCH1(J),J=1,10),SYSN1,QLEN1
904      FORMAT(3X,'STATUA , VOR -GOTO 13-',/,
        13X,10F4.0,/,3X,'SYSN1=',F3.0,X,'QLEN1=',F3.0)
         GOTO 13
30       CONTINUE

C      6 MIT LCFS-DISZIPLIN
C        -----------------
         DO 33 J=1,10
33       IF(SCH1(J).EQ.0.) GOTO 34
         GOTO 950
34       IF(J.EQ.1.) QLEN1=0.
         IF(J.EQ.1.) GOTO 35
36       SCH1(J)=SCH1(J-1)
         J=J-1
         IF(J.GT.1.) GOTO 36
35       SCH1(1)=NXA
         QLEN1=QLEN1+1.
         SYSN1=SYSN1+1.
         SYSN=SYSN+1.
         SYSNT=SYSNT+1.
         DO 69 J=1,10
         IF(ASTAT(NXA,J).EQ.0.)GOTO 70
69       CONTINUE
70       ASTAT(NXA,J)=1.
         IF(ASTAT(NXA,NUBL).NE.0.) GOTO 62
         GOTO 13
```

Key: 1-with absolute priority 2-determine content of server 1 3-set the status of the set-back single tasks 4-set the status of the set-back joint task and set service time of KN2 temporarily to infinity 5-priority task NXA is set into server 1 6-check whether task NXA is already in the system 7-NXA already present and set-back. Addition of TREST to the service time of NXA 8-seek the second NXA in the loop 9-cancel and set-back the remaining loop

```
C       1MIT ABS. PRIOR
C        --------------
250      CONTINUE
C       2BESTIMMUNG DES INHALTES VON SERVER 1
251      NS1=0
         DO 2510 J=1,20
2510     IF(ASTAT(J,1).EQ.6.8)NS1=J
         DO 252 J=1,20
252      IF((ASTAT(J,1).EQ.3.).OR.(ASTAT(J,1).EQ.8.))NS1=J
C        SERVER 1 LEER ?
         IF(NS1.EQ.0)GOTO 211
C        ELEMENTE DER SCHLANGE 1 WERDEN UM EINEN PLATZ ZURUECK-
C        GESETZT.
         DO 253 J=1,10
253      IF(SCH1(J).EQ.0.)GOTO 254
         GOTO 950
254      IF(J.EQ.1)GOTO 2542
2541     SCH1(J)=SCH1(J-1)
         J=J-1
         IF(J.GE.2)GOTO 2541
C        INHALT DES SERVER 1 WIRD AUF DEN 1.PLATZ DER SCHLANGE 1
C        ZURUCKGESETZT.
2542     SCH1(1)=NS1*1.
         IF(ASTAT(NS1,1).NE.6.8)TREST(NS1)=TIM(1)-THEXT
         QLEN1=QLEN1+1.
         IF(ASTAT(NS1,1).NE.6.8)GOTO 2511
         ASTAT(NS1,1)=6.9
         GOTO 211
2511     IF(ASTAT(NS1,1).EQ.8.)GOTO 231
C       3SETZEN DES STATUS DER ZURUECKGESETZTEN EINZEL-AUFGABE.
         ASTAT(NS1,1)=6.
         GOTO 211
C       4SETZEN DES STATUS DER ZURUECKGESETZTEN GEMEINSAMEN AUFGABE,
C        SOWIE SERVICE-ZEIT VON KN2 VORUEBERGEHEND AUF UNENDLICH.
231      ASTAT(NS1,1)=6.8
         TIM(2)=10.**20.
C       5VORRANGIGE AUFGABE NXA WIRD IN DEN SERVER 1 GESETZT.
211      SYSN1=SYSN1+1.
         SYSN=SYSN+1.
         SYSNT=SYSNT+1.
         CALL USER(NAT,NXA,TIM(1))
         TM=TIM(1)
C       6PRUEFEN,OB AUFGABE NXA BEREITS IM SYSTEM
C        VORHANDEN,ALSO ASTAT(NXA,1)=6.  (WEGEN DISZ=2.)
         IF(ASTAT(NXA,1).NE.6.)GOTO 505
C       7NXA BEREITS VORHANDEN UND ZURUECKGESTELLT.
C        BEAUFSCHLAGUNG DER SERVICE-DAUER VON NXA UM TREST
         TR=TREST(NXA)
         TIM(1)=TIM(1)+TREST(NXA)
         TREST(NXA)=0.
C       8AUFSUCHEN DER DOPPELTEN NXA IN DER SCHLANGE
C       9LOESCHEN UND NACHRUECKEN DER RESTL. SCHLANGE
         DO 506 J=1,9
         IF(SCH1(J).NE.(NXA*1.))GOTO 506
         DO 507 K=J,9
507      SCH1(K)=SCH1(K+1)
         GOTO 508
506      CONTINUE
508      IF(SCH1(10).EQ.(NXA*1.))SCH1(10)=0.
         QLEN1=QLEN1-1.
         SYSN1=SYSN1-1.
         SYSN=SYSN-1.
         SYSNT=SYSNT-1.
         IF(KA.EQ.2)PRINT 909,NXA,TM,TR,TIM(1)
909      FORMAT(3X,'***DOPPELTES AUFTRETEN DER ABS.PRIOR.AUFG.',I3,':',/,
        13X,'***URSPRUENGLICH VORGESEHENES TIM(1): ',F8.2,/,
        13X,'***BEAUFSCHLAGUNG DURCH TREST       : ',F8.2,/,
        13X,'***RESULTIERENDES TIM(1)            : ',F8.2)
505      ASTAT(NXA,1)=3.
         GOTO 13
```

Key: 1-if task can be executed by both channels (either/or), it is given to the smaller loop 2-which loop is shorter 3-if task must be executed simultaneously in both channels 4-assume FCFS discipline 5-print out

```
C      1 WENN AUFGABE VON BEIDEN KANALEN ABGEFERTIGT WERDEN KANN
C        (ENTWEDER/ODER) .WIRD SIE AUF KLEINERE SCHLANGE GEGEBEN
C        ******************************************************
C      2 WELCHE SCHLANGE IST KUERZER ?
C        ------------------------------
10       DO 41 J=1,10
41       IF(SCH1(J).EQ.0.)GOTO 42
42       J1=J
         DO 43 J=1,10
43       IF(SCH2(J).EQ.0.)GOTO 44
44       J2=J
         IF(J1.LE.J2) GOTO 11
         IF(J1.GT.J2) GOTO 12
         GOTO 13

C      3 WENN AUFGABE IN BEIDEN KANAELEN GLEICHZEITIG ABGEDERTIGT
C        WERDEN MUSS
C        ********************************************************
C      4 ANNAHME   FCFS-DISZIPLIN
C        ------------------------
800      KSCH=3
         IF(DISZ(NXA).NE.0.)PRINT 801,NXA,DISZ(NXA)
801      FORMAT(3X,'FALSCHE ANNAHME VON FCFS!',/,3X,
        1'DISZ(',I2,')= ',F2.0)
         DO 802 J=1,10
802      IF(SCH1(J).EQ.0.)GOTO 803
         GOTO 950
803      SCH1(J)=NXA*1.
         DO 804 J=1,10
804      IF(SCH2(J).EQ.0.)GOTO 805
         GOTO 950
805      SCH2(J)=NXA*1.
         SYSN1=SYSN1+1.
         SYSN2=SYSN2+1.
         SYSN=SYSN+1.
         SYSNT=SYSNT+1.
         QLEN1=QLEN1+1.
         QLEN2=QLEN2+1.
         DO 806 J=1,10
806      IF(ASTAT(NXA,J).EQ.0.)GOTO 807
807      ASTAT(NXA,J)=7.
         IF(ASTAT(NXA,NUBL).NE.0.)GOTO 62
         GOTO 13
C        ABBRUCH BEI UEBERLASTUNG DER SCHLANGE
950      IF(KA.EQ.2)PRINT 951,THEXT,NXA,KSCH
         WRITE(7,951)THEXT,NXA,KSCH
951      FORMAT(3X,'THEXT=',F8.2,' STATUA. ABBRUCH BEI AUFTRITT ',
        1'VON AUFGABE',I2,' DURCH UEBERLASTUNG VON SCHLANGE',I2)
         XLAST=FLOAT(NXA)
         RETURN

C      5 AUSDRUCK
C        ********
13       CONTINUE
         NS1=0
         NS2=0
         DO 50 J=1,20
         IF(ASTAT(J,1).EQ.6.0)NS1=J
         IF(ASTAT(J,1).EQ.6.0)NS2=J
50       CONTINUE
         DO 51 J=1,20
         IF((ASTAT(J,1).EQ.3).OR.(ASTAT(J,1).EQ.8.)) NS1=J
         IF((ASTAT(J,1).EQ.4).OR.(ASTAT(J,1).EQ.8.)) NS2=J
51       CONTINUE
         IF(QLEN1.EQ.SYSN1)NS1=0
         IF(QLEN2.EQ.SYSN2)NS2=0
         CALL AUS(NS1,NS2)
         RETURN
         END
```

Key: 1-repositioning of tasks in the waiting loop 2-STATUQ checks whether the element moving into the server is dependent on other tasks of states. If so, the element is set to the end of the loop 3-loop one 4-first element is loop one is checked 5-first element is dependent, the other task is not yet completed. The element is set to the end of the loop 6-print out

```
C       ************************************************************
C      1UP STATUQ ,UMPOSITIONIERUNG DER AUFGABEN IN DER WARTESCHLANGE
C       ************************************************************
C
C      2STATUQ UEBERPRUEFT, OB DAS IN DEN SERVER WANDERNDE ELEMENT
C       VON AMNDREN AUFGABEN ODER ZUSTAENDEN ABHAENGIG IST (AAZ,ZAZ),
C       WENN JA, WIRD DAS ELEMENT AN DAS ENDE DER SCHLANGE GESETZT.
C
        SUBROUTINE STATUQ(NSX,NQ,NS1,NS2,NABS)
C       ------------------------------------
        COMMON/A/ASTAT(20,10),XKZ(20),ZSTAT(20),TZU(20),TREST(20)
        COMMON/AA/AT(20),DISZ(20),ANZX(20),XNUM(20)
        COMMON/B/SCH1(10),SCH2(10),QLEN1,QLEN2,SYSN1,SYSN2,SYSN
        COMMON/C/AAZ(20),APA(20),APB(20),ARR(20),ZAZ(20),AO(20),AU(20)
        COMMON/D/SER(20),SPA(20),SPB(20),XIX(20),YIY(20),
       1TIM(4),TNEXT,TLAST,SO(20),SU(20)
        COMMON/F/XA,XB,XLAST,UBL(20)
        KA=IFIX(XA)
        KB=IFIX(XB)
        NABS=0
C       ABFRAGE DER SCHLANGE:
        GOTO(1,5)NSX
C
C      3S C H L A N G E   1 :
C       ************************************************************
C      4ERSTES ELEMENT IN SCHLANGE 1 WIRD UEBERPRUEFT:
C       *****************************************
1       IF((AAZ(NQ).EQ.0.).AND.(ZAZ(NQ).EQ.0.))GOTO 11
        K=IFIX(AAZ(NQ))
        IF(K.EQ.0)GOTO 230
        IF(ASTAT(K,1).NE.5.) GOTO 200
230     K=IFIX(ZAZ(NQ))
        IF(K.EQ.0)GOTO 11
        IF(ZSTAT(K).EQ.2.)GOTO 200
        GOTO 11
C
C      5ERSTES ELEMENT IST ABHAENGIG,DIE ANDERE AUFGABE NOCH
C       NICHT FERTIG. DAS ELEMENT WIRD ANS ENDE DER SCHLANGE
C       GESETZT.
C       ---------------------------------------------------
200     DO 30 J=1,10
        IF(SCH1(J).EQ.0.) GOTO 31
30      CONTINUE
31      SCH1(J)=SCH1(1)
C       AUFRUECKEN DER SCHLANGE
        JM=J-1
        DO 32 J=1,JM
        SCH1(J)=SCH1(J+1)
32      CONTINUE
        SCH1(JM+1)=0.
        DO 50 J=1,10
50      IF(ASTAT(NQ,J).EQ.0.)GOTO 51
51      JM=J
        ASTAT(NQ,J)=ASTAT(NQ,1)
        DO 52 J=1,JM
52      ASTAT(NQ,J)=ASTAT(NQ,J+1)
C
C      6AUSDRUCK
C       --------
        NQ=SCH1(1)
        JOT=1
        IF(KA.GT.0)WRITE(7,997)JOT
        IF(KA.EQ.2)PRINT 997,JOT
        NS1=0
        NS2=0
        DO 799 J=1,20
799     IF(ASTAT(J,1).EQ.6.0)NS2=J
        DO 800 J=1,20
800     IF((ASTAT(J,1).EQ.4.).OR.(ASTAT(J,1).EQ.8.))NS2=J
        IF(QLEN2.EQ.SYSN2)NS2=0
        CALL AUS(NS1,NS2)
```

Key: 1-check wheter any element can be processed in the loop
2-first element of loop one is set into server 1
3-single element is set in server 4-the part of a joint task to be set into the server had been set back; compute remaining service time in both servers 5-reset part of joint task is set in server 6-move other elements in the loop back 7-determine the element in the 2nd server 8-print out

```
C      1 UEBERPRUEFUNG, OB UEBERHAUPT EIN ELEMENT DER SCHLANGE
C        ABGEFERTIGT WERDEN KANN
C        ----------------------------------------------------
         DO 700 J=1,10
         K=IFIX(SCH1(J))
         IF(K.EQ.0) GOTO 702
         L=IFIX(AAZ(K))
         M=IFIX(ZAZ(K))
         IF(L.EQ.0.AND.M.EQ.0) GOTO 701
         IF(L.EQ.0) GOTO 301
         IF(ASTAT(L,1).NE.5.) GOTO 699
         IF(M.EQ.0)GOTO 701
301      IF(ZSTAT(M).EQ.2.) GOTO 699
         GOTO 701
699      CONTINUE
700      CONTINUE
702      CONTINUE
         IF(KA.GT.0)WRITE(7,703)
         IF(KA.EQ.2)PRINT 703
703      FORMAT(3X,'KEIN SERVICE IN SCH1 MOEGLICH')
         RETURN
701      CONTINUE
         GOTO 1
C      2 ERSTES ELEMENT DER SCHLANGE 1 WIRD IN DEN SERVER 1 GESETZT
C        ************************************************************
11       IF(AT(NQ).EQ.3.)GOTO 520
         IF(ASTAT(NQ,1).NE.6.)GOTO 220
C        DAS IN DEN SERVER ZU SETZENDE EINZEL-ELEMENT WAR
C        ZURUECKGESTELLT WORDEN,BERECHNUNG DER RESTLICHEN SERVICE-ZEIT:
         TIM(1)=TNEXT+TREST(NQ)
         TREST(NQ)=0.
         NABS=1
C      3 EINZELNES ELEMENT WIRD IN SERVER GESETZT
220      ASTAT(NQ,1)=3.
         NS1=NQ
         GOTO 2
520      IF(ASTAT(NQ,1).NE.6.8)GOTO 4000
C      4 DER IN DEN SERVER ZU SETZENDE TEIL EINER GEMEINSAMEN AUFGABE
C        WAR ZURUECKGESTELLT WORDEN,BERECHNUNG DER RESTLICHEN SERVICE-
C        ZEIT IN BEIDEN SERVERN:
         TIM(1)=TNEXT+TREST(NQ)
         TIM(2)=TIM(1)
         TREST(NQ)=0.
         NABS=1
C      5 ZURUECKGESTELLTER TEIL DER GEMEINSAMEN AUFGABE WIRD IN DEN
C        SERVER GESETZT
         ASTAT(NQ,1)=8.
         NS1=NQ
         GOTO 2
4000     IF(ASTAT(NQ,1).NE.6.9)GOTO 400
         TIM(1)=10.**20.
         NABS=1
         NS1=NQ
         ASTAT(NQ,1)=6.8
C      6 NACHRUECKEN DER ANDEREN ELEMENTE IN DER SCHLANGE
2        DO 3 J=1,10
3        IF(SCH1(J).EQ.0.)GOTO 4
4        JMAX=J
         DO 521 J=1,JMAX-1
521      SCH1(J)=SCH1(J+1)
         QLEN1=QLEN1-1.
C      7 ERMITTLUNG DES ELEMENTES IM 2.SERVER
         NS2=0
         DO 801 J=1,20
801      IF(ASTAT(J,1).EQ.6.8)NS2=J
         DO 798 J=1,20
798      IF((ASTAT(J,1).EQ.4.).OR.(ASTAT(J,1).EQ.8.))NS2=J
         IF(QLEN2.EQ.SYSN2)NS2=0
C      8 AUSDRUCK
         JOT=2
         IF(KA.GT.0)WRITE(7,997)JOT
         IF(KA.EQ.2)PRINT 997,JOT
         CALL AUS(NS1,NS2)
         GOTO 26
```

Key: 1-server 1 is free. Check whether server 2 is also free for joint task 2-server two is also empty 3-server two is full 4-check whether there is any task in loop one which can only be processed in server one 5-loop two 6-first element in loop 2 is checked 7-first element is dependent, the other task is not yet finished. The element is set to the end of the loop 8-advance the loop

```
C       1 SERVER 1 IST FREI. PRUEFUNG, OB SERVER 2 FUER
C         GEMEINSAME AUFGABE EBENFALLS FREI IST.
C         ********************************************
400       DO 401 J=1,20
401       IF((ASTAT(J,1).EQ.4.).OR.(ASTAT(J,1).EQ.8.))GOTO 402
C       2 SERVER 2 IST AUCH LEER.
          IF(SCH2(1).EQ.(NQ*1.))GOTO 403
C         SCH2 MUSS UMGEORDNET WERDEN:
          DO 510 J=1,10
          IF(SCH2(J).EQ.(NQ*1.))GOTO 511
510       CONTINUE
511       JC=J
          DO 512 J=1,JC-1
512       SCH2(JC+1-J)=SCH2(JC-J)
          SCH2(1)=NQ*1.
          GOTO 403
C       3 SERVER 2 IST VOLL.
C         -----------------
402       IF(QLEN1.LE.1.)GOTO 420
C       4 UEBERPRUEFUNG OB IN SCH1 UEBERHAUPT EINE AUFGABE VORHANDEN,
C         DIE NUR IN SERVER 1 BEARBEITET WERDEN KOENNTE:
          DO 500 J=2,10
          IF(SCH1(J).EQ.0.)GOTO 500
          NAUF=IFIX(SCH1(J))
          IF(AT(NAUF).EQ.3.)GOTO 500
          L=IFIX(AAZ(NAUF))
          M=IFIX(ZAZ(NAUF))
          IF((L.EQ.0).AND.(M.EQ.0))GOTO 200
          IF(L.EQ.0)GOTO 399
          IF(ASTAT(L,1).NE.5.)GOTO 500
399       IF(M.EQ.0)GOTO 200
          IF(ASTAT(M,1).EQ.5.)GOTO 200
500       CONTINUE
420       NS1=0
          DO 501 J=1,20
501       IF(ASTAT(J,1).EQ.6.0)NS2=J
          DO 795 J=1,20
795       IF((ASTAT(J,1).EQ.4.).OR.(ASTAT(J,1).EQ.8.))NS2=J
          IF(QLEN2.EQ.SYSN2)NS2=0
          IF(KA.GT.0)WRITE(7,703)
          IF(KA.EQ.2)PRINT 703
          CALL AUS(NS1,NS2)
          GOTO 26


C       5 S C H L A N G E   2 :
C         ***********************************************************
C       6 ERSTES ELEMENT IN SCHLANGE 2 WIRD UEBERPRUEFT:
C         ********************************************
5         IF((AAZ(NQ).EQ.0.).AND.(ZAZ(NQ).EQ.0.))GOTO 22
          K=IFIX(AAZ(NQ))
          IF(K.EQ.0)GOTO 231
          IF(ASTAT(K,1).NE.5.) GOTO 201
231       K=IFIX(ZAZ(NQ))
          IF(K.EQ.0)GOTO 22
          IF(ZSTAT(K).EQ.2.)GOTO 201
          GOTO 22
C         ERSTES ELEMENT IST ABHAENGIG,DIE ANDERE AUFGABE NOCH
C       7 NICHT FERTIG. DAS ELEMENT WIRD ANS ENDE DER SCHLANGE
C         GESETZT.
C         ----------------------------------------------------
201       DO 40 J=1,10
          IF(SCH2(J).EQ.0.) GOTO 41
40        CONTINUE
41        SCH2(J)=SCH2(1)
C       8 AUFRUECKEN DER SCHLANGE
          JM=J-1
          DO 42 J=1,JM
          SCH2(J)=SCH2(J+1)
42        CONTINUE
          SCH2(JM+1)=0.
          DO 53 J=1,10
53        IF(ASTAT(NQ,J).EQ.0.)GOTO 54
54        JM=J
```

Key: 1-check whether any element of the loop can be processed
2-first element of loop 2 is set into server 2
3-single element is set into server 4-the part of a joint task to be set into the server had been set back; calculate the remaining service time in both servers 5-reset part of joint task is set into the server

```
      ASTAT(NQ,J)=ASTAT(NQ,1)
      DO 55 J=1,JM
55    ASTAT(NQ,J)=ASTAT(NQ,J+1)
C     AUSDRUCK
C     --------
      NQ=SCH2(1)
      JOT=3
      IF(KA.GT.0)WRITE(7,997)JOT
      IF(KA.EQ.2)PRINT 997,JOT
      NS1=0
      NS2=0
      DO 797 J=1,20
797   IF(ASTAT(J,1).EQ.6.8)NS1=J
      DO 802 J=1,20
802   IF((ASTAT(J,1).EQ.3.).OR.(ASTAT(J,1).EQ.8.))NS1=J
      IF(QLEN1.EQ.SYSN1)NS1=0
      CALL AUS(NS1,NS2)
C   1 UEBERPRUEFUNG, OB UEBERHAUPT EIN ELEMENT DER SCHLANGE
C     ABGEFERTIGT WERDEN KANN
C     ------------------------------------------------------
      DO 704 J=1,10
      K=IFIX(SCH2(J))
      IF(K.EQ.0) GOTO 706
      L=IFIX(AAZ(K))
      M=IFIX(ZAZ(K))
      IF(L.EQ.0.AND.M.EQ.0) GOTO 705
      IF(L.EQ.0) GOTO 300
      IF(ASTAT(L,1).NE.5.) GOTO 698
300   IF(M.EQ.0)GOTO 705
      IF(ZSTAT(M).EQ.2.) GOTO 698
      GOTO 705
698   CONTINUE
704   CONTINUE
706   CONTINUE
      IF(KA.GT.0)WRITE(7,707)
      IF(KA.EQ.2)PRINT 707
707   FORMAT(3X,'KEIN SERVICE IN SCH2 MOEGLICH')
      RETURN
705   CONTINUE
      GOTO 5
C   2 ERSTES ELEMENT DER SCHLANGE 2 WIRD IN DEN SERVER 2 GESETZT
C     ***********************************************************
22    IF(AT(NQ).EQ.3.)GOTO 570
      IF(ASTAT(NQ,1).NE.6.)GOTO 221
C     DAS IN DEN SERVER ZU SETZENDE EINZEL-ELEMENT WAR
C     ZURUECKGESTELLT WORDEN.BERECHNUNG DER RESTLICHEN SERVICE-ZEIT:
      TIM(2)=TNEXT+TREST(NQ)
      TREST(NQ)=0.
      NABS=1
C   3 EINZELNES ELEMENT WIRD IN SERVER GESETZT
221   ASTAT(NQ,1)=4.
      NS2=NQ
      GOTO 23
570   IF(ASTAT(NQ,1).NE.6.8)GOTO 4040
C   4 DER IN DEN SERVER ZU SETZENDE TEIL EINER GEMEINSAMEN AUFGABE
C     WAR ZURUECKGESTELLT WORDEN.BERECHNUNG DER RESTLICHEN SERVICE-
C     ZEIT IN BEIDEN SERVERN:
      TIM(2)=TNEXT+TREST(NQ)
      TIM(1)=TIM(2)
      TREST(NQ)=0.
      NABS=1
C   5 ZURUECKGESTELLTER TEIL DER GEMEINSAMEN AUFGABE WIRD IN DEN
C     SERVER GESETZT
      ASTAT(NQ,1)=8.
      NS2=NQ
      GOTO 23
4040  IF(ASTAT(NQ,1).NE.6.9)GOTO 404
      TIM(2)=10.**20.
      NABS=1
      NS2=NQ
      ASTAT(NQ,1)=6.8
```

Key: 1-set-back of the other elements in the loop 2-determine the element in the 1st server 3-printout 4-server two is free. Check whether server one is also free for joint task 5-server one is full 6-check whether there is any task in loop two which could only be processed in server two 7-joint task moves up in both servers 8-advance of the queues

```
C      1 NACHRUECKEN DER ANDEREN ELEMENTE IN DER SCHLANGE
23       DO 24 J=1,10
24       IF(SCH2(J).EQ.0.)GOTO 25
25       JMAX=J
         DO 571 J=1,JMAX-1
571      SCH2(J)=SCH2(J+1)
         QLEN2=QLEN2-1.
C      2 ERMITTLUNG DES ELEMENTES IM 1.SERVER
         NS1=0
         DO 883 J=1,20
883      IF(ASTAT(J,1).EQ.6.8)NS1=J
         DO 796 J=1,20
796      IF((ASTAT(J,1).EQ.3.).OR.(ASTAT(J,1).EQ.8.))NS1=J
         IF(QLEN1.EQ.SYSN1)NS1=0
C      3 AUSDRUCK
         JOT=4
         IF(KA.GT.0)WRITE(7,997)JOT
         IF(KA.EQ.2)PRINT 997,JOT
         CALL AUS(NS1,NS2)
         GOTO 26

C        SERVER 2 IST FREI. PRUEFUNG, OB SERVER 1 FUER
C      4 GEMEINSAME AUFGABE EBENFALLS FREI IST.
C        ********************************************
404      DO 405 J=1,20
405      IF((ASTAT(J,1).EQ.3.).OR.(ASTAT(J,1).EQ.8.))GOTO 406
C        SERVER 1 IST AUCH LEER.
         IF(SCH1(1).EQ.(NQ*1.))GOTO 403
C        SCH1 MUSS UMGEORDNET WERDEN.
         DO 560 J=1,10
         IF(SCH1(J).EQ.(NQ*1.))GOTO 561
560      CONTINUE
561      JC=J
         DO 562 J=1,JC-1
562      SCH1(JC+1-J)=SCH1(JC-J)
         SCH1(1)=NQ*1.
         GOTO 403
C      5 SERVER 1 IST VOLL.
C        ----------------
406      IF(QLEN2.LE.1.)GOTO 421
C      6 UEBERPRUEFUNG OB IN SCH2 UEBERHAUPT EINE AUFGABE VORHANDEN,
C        DIE NUR IN SERVER 2 BEARBEITET WERDEN KOENNTE.
         DO 550 J=2,10
         IF(SCH2(J).EQ.0.)GOTO 550
         NAUF=IFIX(SCH2(J))
         IF(AT(NAUF).EQ.3.)GOTO 550
         L=IFIX(QAZ(NAUF))
         M=IFIX(ZAZ(NAUF))
         IF((L.EQ.0).AND.(M.EQ.0))GOTO 201
         IF(L.EQ.0)GOTO 449
         IF(ASTAT(L,1).NE.5.)GOTO 550
449      IF(M.EQ.0)GOTO 201
         IF(ASTAT(M,1).EQ.5.)GOTO 201
550      CONTINUE
421      NS2=0
         DO 551 J=1,20
551      IF(ASTAT(J,1).EQ.6.8)NS1=J
         DO 794 J=1,20
794      IF((ASTAT(J,1).EQ.3.).OR.(ASTAT(J,1).EQ.8.))NS1=J
         IF(QLEN1.EQ.SYSN1)NS1=0
         IF(KA.GT.0)WRITE(7,707)
         IF(KA.EQ.2)PRINT 707
         CALL AUS(NS1,NS2)
         GOTO 26

C      7 GEMEINSAME AUFGABE RUECKT IN BEIDE SERVER AUF
C        ********************************************
403      ASTAT(NQ,1)=8.
         NS1=NQ
         NS2=NQ
C      8 AUFRUECKEN DER SCHLANGEN
C        ----------------------
         DO 407 J=1,10
407      IF(SCH1(J).EQ.0.)GOTO 408
408      DO 409 K=1,J-1
409      SCH1(K)=SCH1(K+1)
```

Key: 1- UP STATUS, Simulation of the effects on further processing, caused by execution of a task 2-subroutine status 3-check whethre task has been finally worked off due to the number of its occurrances 4-for phase two only, calculate the end time/appr. check 5-for phase three only, calculate the decision land/go around 6-first decision state

```
      DO 410 J=1,10
410   IF(SCH2(J).EQ.0.)GOTO 411
411   DO 412 K=1,J-1
412   SCH2(K)=SCH2(K+1)
      QLEN1=QLEN1-1.
      QLEN2=QLEN2-1.
C     AUSDRUCK
C     --------
      JOT=5
      IF(KA.GT.0)WRITE(7,997)JOT
      IF(KA.EQ.2)PRINT 997,JOT
      IF(QLEN1.EQ.SYSN1)NS1=0
      IF(QLEN2.EQ.SYSN2)NS2=0
      CALL AUS(NS1,NS2)
26    CONTINUE
997   FORMAT(3X,'STATUQ-',I1,',')
      RETURN
      END


C     ***************************************************************
C   1 UP STATUS ,SIMULATION DER AUSWIRKUNGEN,DIE DURCH BEARBEITUNG
C                EINER AUFGABE FUER DEN WEITEREN ABLAUF ENTSTEHEN
C     ***************************************************************
    2 SUBROUTINE STATUS(NSX,NPH,DAUER)
C     ------------------------------
      COMMON/A/ASTAT(20,10),XKZ(20),ZSTAT(20),TZU(20),TREST(20)
      COMMON/AA/AT(20),DISZ(20),ANZX(20),XNUM(20)
      COMMON/C/AAZ(20),APA(20),APB(20),ARR(20),ZAZ(20),AO(20),AU(20)
      COMMON/D/SER(20),SPA(20),SPB(20),XIX(20),YIY(20),
     1TIM(4),THEXT,TLAST,SO(20),SU(20)
      COMMON/F/XA,XB,XLAST,UBL(20)
      COMMON/HH/TOM,TDH,USI,USF,XGA,E1,E2,TE1,TE2,TFCH,TACH,TABR
      KA=IFIX(XA)
      KB=IFIX(XB)
      IF((NSX.LT.1).OR.(NSX.GT.20))GOTO 999
C   3 UEBERPRUEFUNG, OB AUFG. DURCH ANZAHL DES AUFTRETENS END-
C     GUELTIG ABGEARBEITET IST
C     ***************************************************
      ASTAT(NSX,1)=0.
      DO 101 J=2,10
101   IF(ASTAT(NSX,J).EQ.0.)GOTO 102
102   JM=J-1
      DO 103 J=1,JM
103   ASTAT(NSX,J)=ASTAT(NSX,J+1)
      IF(ASTAT(NSX,1).NE.0.)GOTO 104
      IF(XKZ(NSX).GE.ANZX(NSX))ASTAT(NSX,1)=5.
104   CONTINUE
C   4 NUR FUER PHASE 2: BERECHNUNG DES
C     ENDZEITPUNKTES/APPR.CHECK
C     ********************************
      IF(NPH.NE.2)GOTO 120
      IF(NSX.EQ.4)TACH=THEXT
      IF(NSX.EQ.6)TABR=THEXT

C   5 NUR FUER PHASE 3: BERECHNUNG DER ENTSCHEIDUNG LANDEN/GO AROUND
C     ***************************************************************
120   IF(NPH.NE.3)GOTO 106
      IF(NSX.EQ.11)GOTO 111
      IF(NSX.EQ.12)GOTO 112
      GOTO 105

C   6 1.ENTSCHEIIDUNGS-STUFE - F.I.S.
111   CALL EMOD(1,THEXT,E,DAUER)
      E1=E
      TE1=THEXT
      GOTO 105
```

Key: 1-second decision stage 2-determination of the content of CM1/2 3-print out 4-determine the next occurring task and its arrival time 5-first callup of UARR in approach 6-UARR has been called up for the first time 7-for all tasks the arrival potential (from AWA) and the first arrival time are determined

```
C     1 2.ENTSCHEIDUNGS-STUFE - CONT/GA.
112       CALL ENOD(2,TNEXT,E,DAUER)
          E2=E
          TE2=TNEXT
          IF(E2.EQ.3.)XGA=1.

105       IF(NSX.EQ.5)TFCH=TNEXT

C     2 BESTIMMUNG DES INHALTES VON CM1/CM2
C       ***********************************
106       NK=IFIX(AT(NSX))
          IF(NK.EQ.0)NK=4
          NS1=0
          NS2=0
          GOTO(501,502,505,504)NK
501       DO 510 J=1,20
          IF(ASTAT(J,1).EQ.6.0)NS2=J
510       CONTINUE
          DO 511 J=1,20
          IF((ASTAT(J,1).EQ.4.).OR.(ASTAT(J,1).EQ.8.))NS2=J
511       CONTINUE
          GOTO 505
502       DO 512 J=1,20
          IF(ASTAT(J,1).EQ.6.0)NS1=J
512       CONTINUE
          DO 513 J=1,20
          IF((ASTAT(J,1).EQ.3.).OR.(ASTAT(J,1).EQ.8.))NS1=J
513       CONTINUE
          GOTO 505
504       DO 109 J=1,20
          IF(ASTAT(J,1).EQ.6.0)NS1=J
          IF(ASTAT(J,1).EQ.6.0)NS2=J
109       CONTINUE
          DO 110 J=1,20
          IF((ASTAT(J,1).EQ.3.).OR.(ASTAT(J,1).EQ.8.))NS1=J
          IF((ASTAT(J,1).EQ.4.).OR.(ASTAT(J,1).EQ.8.))NS2=J
110       CONTINUE
          IF(QLEN1.EQ.SYSN1)NS1=0
          IF(QLEN2.EQ.SYSN2)NS2=0

C     3 AUSDRUCK
C       ********
505       IF(KA.EQ.2)PRINT 997
997       FORMAT(3X,'STATUS:')
          CALL AUS(NS1,NS2)
999       RETURN
          END

C       **************************************************************
C       UP UARR ,BESTIMMUNG DER NAECHSTEN AUFTRETENDEN AUFGABE UND DES
C     4          AUFTRITTSZEITPUNKTES
C       **************************************************************

          SUBROUTINE UARR(NAT,TMIN,KAMIN,NPH,DAUER,KWA,IW1,IW2)
C         ---------------------------------------------------
          COMMON/A/ASTAT(20,10),XKZ(20),ZSTAT(20),TZU(20),TREST(20)
          COMMON/AA/AT(20),DISZ(20),ANZX(20),XNUM(20)
          COMMON/C/AAZ(20),APA(20),APB(20),ARR(20),ZAZ(20),AO(20),AU(20)
          COMMON/D/SER(20),SPA(20),SPB(20),XIX(20),YIY(20),
          1TIM(4),TNEXT,TLAST,SO(20),SU(20)
          COMMON/E/ZEIT(20),RAUF(20)
          COMMON/F/XA,XB,XLAST,UBL(20)
          COMMON/H/XNAT(20),A(20),B(20),TN(20),PBZ(20),AWA(20)
          COMMON/HA/TOM,TDH,USI,USF,XGA,E1,E2,TE1,TE2,TFCH,TACH,TABR
          KA=IFIX(XA)
          KB=IFIX(XB)

C     5 1.AUFRUF VON UARR IM ANFLUG?
          IF(KAMIN.NE.0)GOTO 31
C     6- UARR IST ZUM ERSTEN MAL AUFGERUFEN
C       ------------------------------
C     7 ES WERDEN FUER ALLE AUFGABEN DIE AUFTRITTS-
C       MOEGLICHKEIT (AUS AWA) UND DIE 1.AUFTRITTSZEIT BESTIMMT
```

Key: 1-time 2-determine arrival potential 3-if task X depends on task Y, then task Y does not appear (since AWA Less than one and RAUF=0), it is assumed that task Y was already executed in the preceeding phase and we set ASTAT(Y,1)=5
4-UARR is called up again 5-exponential distribution
6-Erlang distribution

```
          DO 3 I=1,20
        1 ZEIT(I)=10.**30.
          RAUF(I)=0.
3         CONTINUE
C       2 BESTIMMUNG DER AUFTRITTSMOEGLICHKEIT RAUF
          DO 106 I=1,NAT
106       RAUF(I)=1.
          IF(KWA.NE.1)GOTO 103
          DO 100 I=1,NAT
          WA=RAN(IW1,IW2)
          IF(WA.GT.AWA(I))RAUF(I)=0.
100       CONTINUE
103       CONTINUE

C       3 IST AUFGABE X VON AUFGABE Y ABHAENGIG, AUFGABE Y TRITT
C         ABER NICHT AUF (DA AWA<1 UND RAUF=0) SO WIRD ANGENOMMEN,
C         DASS AUFGABE Y BEREITS IN DER VOANGEGANGENEN PHASE BEARBEITET
C         WURDE UND ES WIRD ASTAT(Y,1)=5. GESETZT.
          IF(NPH.NE.2)GOTO 107
          IF(RAUF(14).LT.1.)ASTAT(14,1)=5.
          IF(RAUF(6).LT.1.)ASTAT(6,1)=5.
107       IF(NPH.NE.3)GOTO 108
          IF(RAUF(5).LT.1.)ASTAT(5,1)=5.
          IF(RAUF(9).LT.1.)ASTAT(9,1)=5.
          IF(RAUF(10).LT.1.)ASTAT(10,1)=5.
108       CONTINUE
          KAMIN=0

C       4 UARR WIRD ZUM WIEDERHOLTEN MALE AUFGERUFEN.
C         ----------------------------------------
C         ES WIRD NUR NOCH EINE EINZIGE AUFTR.ZEIT BERECHNET,
C         DIE DO-SCHLEIFE DESHALB UEBERSPRUNGEN
31        IZZ=0
          IF(KAMIN.EQ.0)GOTO 5
          J=KAMIN
          IZZ=1
          GOTO 6

5         CONTINUE
          DO 7 J=1,NAT

6         CONTINUE
          IF(RAUF(J).LT.1.)GOTO 50
          IF(ARR(J).EQ.1.)GOTO 2
          IF(ARR(J).EQ.2.)GOTO 30

C       5 EXPONENTIAL-VERTEILUNG
C         **********************
40        XLAM=APA(J)
          CALL RANDUX(J,R1)
          ZEIT(J)=-(1./XLAM)*ALOG(R1)
          IF(ZEIT(J).LT.AU(J))GOTO 40
          IF(ZEIT(J).GT.AO(J))GOTO 40
          IF((KAMIN.EQ.0).AND.(ZEIT(J).GE.DAUER))GOTO 40
          GOTO 1

C       6 ERLANG-VERTEILUNG
C         ****************
2         XLAM=APA(J)
          K=IFIX(APB(J))
          PROD=1.
          DO 20 L=1,K
          CALL RANDUX(J,R1)
20        PROD=PROD*R1
          ZEIT(J)=-(1./(K*XLAM))*ALOG(PROD)
          IF(ZEIT(J).LT.AU(J))GOTO 2
          IF(ZEIT(J).GT.AO(J))GOTO 2
          IF((KAMIN.EQ.0).AND.(ZEIT(J).GE.DAUER))GOTO 2
          GOTO 1
```

Key: 1-normal distribution 2-calculate the arrival time 3-determine the timepoint without phase reference 4-determine timepoint for 5-in phase three for A11 and A12 ref. to phase end 6-determine timepoint with phase ref. 7-time 8-no appearance of task is possible 9-check for frequency of occurrence 10-determine the time minimum

```
C       1 NORMAL-VERTEILUNG
C         *****************
30        XM=APA(J)
          SQ=SQRT(APB(J))
          CALL RANDUX(J,R1)
          CALL RANDUX(J,R2)
          T1=COS(2.*3.14159*R2)
          T2=(-2.*ALOG(R1))**0.5
          ZEIT(J)=XM+SQ*T1*T2
          IF(ZEIT(J).LT.AU(J))GOTO 30
          IF(ZEIT(J).GT.AO(J))GOTO 30
          IF((KAMIN.EQ.0).AND.(ZEIT(J).GE.DAUER))GOTO 30

C       2 BERECHNUNG DES AUFTRITTSZEITPUNKTES
C         **********************************
1         IF(NPH.NE.3)GOTO 200
C       5 IN PHASE 3 BEI A11 UND A12 BEZUG AUF PHASENENDE:
          IF(J.EQ.5)GOTO 500
          IF(J.EQ.11)GOTO 300
          IF(J.EQ.12)GOTO 400
C       6 BESTIMMUNG DES ZEITPUNKTES BEI PHASENBEZUG:
200       IF(PBZ(J).NE.1.)GOTO 201
        7 ZEIT(J)=ZEIT(J)*DAUER
          GOTO 12
C       3 BESTIMMUNG DES ZEITPUNKTES OHNE PHASENBEZUG:
201       ZEIT(J)=TNEXT+ZEIT(J)*60.
          GOTO 12
C       4 BESTIMMUNG DES ZEITPUNKTES FUER A11/12 IN PHASE 3:
300     7 ZEIT(11)=DAUER-ZEIT(11)
          IF(ZEIT(11).LT.0.)GOTO 6
          GOTO 12
400     7 ZEIT(12)=TDH-ZEIT(12)
          IF(ZEIT(12).LT.0.)GOTO 6
          GOTO 12
500       ZEIT(5)=TOM
          GOTO 12

C       8 KEIN AUFTRETEN DER AUFGABE MOEGLICH
C         **********************************
50      7 ZEIT(J)=10.**30.

C       9 UEBERPRUEFUNG AUF HAEUFIGKEIT DES AUFTRETENS
C         ******************************************
12        IF(XKZ(J).LT.ANZX(J))GOTO 10
        7 ZEIT(J)=10.**30.
10        CONTINUE

          IF(IZZ.EQ.1)GOTO 8
7         CONTINUE

C      10 ERMITTLUNG DES MINIMUM VON ZEIT(J)
C         *********************************
8         TMIN=ZEIT(1)
          KAMIN=1
          DO 4 J=2,NAT
          IF(ZEIT(J).LT.TMIN)KAMIN=J
          IF(ZEIT(J).LT.TMIN)TMIN=ZEIT(J)
4         CONTINUE

          RETURN
          END
```

Key: 1-determine the task processing time 2-exponential distribution 3-Erlang distribution 4-normal distribution

```
C       *********************************************************
C     1 UP USER ,BESTIMMUNG DER BEARBEITUNGSDAUER EINER AUFGABE
C       *********************************************************

        SUBROUTINE USER(NAT,NS,TIME)
        ----------------------------
C
        COMMON/A/ASTAT(20,10),XKZ(20),ZSTAT(20),TZU(20),TREST(20)
        COMMON/AA/AT(20),DISZ(20),ANZX(20),XNUM(20)
        COMMON/D/SER(20),SPA(20),SPB(20),XIX(20),YIY(20),
       1TIM(4),TNEXT,TLAST,SO(20),SU(20)
        IF(NS.NE.0)GOTO 3
        TIME=10.**30.
        GOTO 2
3       CONTINUE

4       IF(SER(NS).EQ.1.)GOTO 1
        IF(SER(NS).EQ.2.)GOTO 20
        IF(SER(NS).EQ.0.)GOTO 10

C     2 EXPONENTIAL-VERTEILUNG
C       **********************
10      XMU=SPA(NS)
        CALL RANDUX(NS,RAN)
        TIME=-(1./XMU)*ALOG(RAN)
        IF(TIME.LT.SU(NS))GOTO 10
        IF(TIME.GT.SO(NS))GOTO 10
        TIME=TNEXT+TIME
        GOTO 2

C     3 ERLANG-VERTEILUNG
C       *****************
1       CONTINUE
32      XLAM=SPA(NS)
        K=IFIX(SPB(NS))
        PROD=1.
        DO 21 L=1,K
        CALL RANDUX(NS,RAN)
21      PROD=PROD*RAN
        TIME=-(1./(K*XLAM))*ALOG(PROD)
        IF(TIME.LT.SU(NS))GOTO 32
        IF(TIME.GT.SO(NS))GOTO 32
        TIME=TNEXT+TIME
        GOTO 2

C     4 NORMAL-VERTEILUNG
C       *****************
20      XM=SPA(NS)
        SQ=SQRT(SPB(NS))
        CALL RANDUX(NS,R1)
        CALL RANDUX(NS,R2)
        T1=COS(2.*3.14159*R2)
        T2=(-2.*ALOG(R1))**0.5
        TIME=XM+SQ*T1*T2
        IF(TIME.LT.SU(NS))GOTO 20
        IF(TIME.GT.SO(NS))GOTO 20
        TIME=TNEXT+TIME

2       IF(AT(NS).EQ.3.)TIM(1)=TIME
        IF(AT(NS).EQ.3.)TIM(2)=TIME
        RETURN
        END
```

Key: 1-determine a random no. using uniform distribution 2-printout the instantaneous system status 3-identifier for output of loop 4-id. for output of values 5-no printout 6-printout to TT or LP 7-unit number

```
C       ************************************************************
C     1 UP RANDUX ,BESTIMMUNG EINER ZUFALLSZAHL 0<X<1 NACH GLEICHVERT.
C       ************************************************************

        SUBROUTINE RANDUX(J,RANDU)
C       --------------------------
        COMMON/D/SER(20),SPA(20),SPB(20),XIX(20),YIY(20),
        1TIM(4),TNEXT,TLAST,SO(20),SU(20)

        IX=IFIX(XIX(J))
        IY=IFIX(YIY(J))

        RANDU=RAN(IX,IY)

        XIX(J)=IX*1.
        YIY(J)=IY*1.

        RETURN

        END

C       ***************************************************
C     2 UP AUS , AUSDRUCKEN DES MOMENTANEN SYSTEMZUSTANDS
C       ***************************************************

        SUBROUTINE AUS(NS1,NS2)
C       -----------------------
        COMMON/A/ASTAT(20,10),XKZ(20),ZSTAT(20),TZU(20),TREST(20)
        COMMON/AA/AT(20),DISZ(20),ANZX(20),XNUM(20)
        COMMON/B/SCH1(10),SCH2(10),QLEN1,QLEN2,SYSN1,SYSN2,SYSN
        COMMON/D/SER(20),SPA(20),SPB(20),XIX(20),YIY(20),
        1TIM(4),TNEXT,TLAST,SO(20),SU(20)
        COMMON/F/XA,XB,XLAST,UBL(20)
        DIMENSION JJ(20)

        KA=IFIX(XA)
        KB=IFIX(XB)
        IF((KA.EQ.0).AND.(KB.EQ.0))GOTO 1000
C
C
C     3 KA=KENNZIFFER FUER AUSDRUCK DER SCHLANGE
C     4 KB=KENNZIFFER FUER AUSDRUCK DER WERTE QLEN,ASTAT,SYSN...

C     5 KA,KB= 0 -- KEIN AUSDRUCK
C     6 KA,KB> 0 -- AUSDRUCK AUF TT BZW LP

1       FORMAT(3X,'T=',F6.2,8X,10F4.0,5X,'/',I4,'/',/)
2       FORMAT(3X,'T=',F6.2,3X,'QLEN1= ',F4.0,2X,'SYSN1= ',F4.0,2X,
        1'QLEN2= ',F4.0,2X,'SYSN2= ',F4.0,2X,'SYSN= ',F4.0)
31    7 FORMAT(/,3X,'EINHEIT NUMMER: ',I4,9I4)
311     FORMAT(3X,'    -    -    -    -    -    -    -    -',
        1'    -    -')
32      FORMAT(3X,'----------------------------------------------------',
        1'--------------------------')
222     FORMAT(10X,'STATUS  :   ',10F4.1)
223     FORMAT(/,10X,'ZUSTAND: ',10F4.0)
224     FORMAT(10X,'TZU     :   ',10F4.1)
225     FORMAT(10X,'TREST   :   ',10F4.1)
226     FORMAT(10X,'TIM(4)  :   ',4(2XE10.4),/)

        IF(KA.EQ.0)GOTO 1000

        NDEV=7

        DO 50 J=1,20
50      JJ(J)=J

100     WRITE(NDEV,1)TNEXT,(SCH1(11-LL),LL=1,10),NS1
        WRITE(NDEV,1)TNEXT,(SCH2(11-LL),LL=1,10),NS2

        WRITE(NDEV,2)TNEXT,QLEN1,SYSN1,QLEN2,SYSN2,SYSN
        WRITE(NDEV,31)(JJ(KK),KK=1,10)
        WRITE(NDEV,311)
```

Key: 1-modelling the landing decision in final

```
      DO 200 J=1,10
      SUM=0.
      DO 51 K=1,10
51    SUM=SUM+ASTAT(K,J)
      IF((J.GT.1).AND.(SUM.EQ.0.))GOTO 300
      WRITE(NDEV,222)(ASTAT(K,J),K=1,10)
200   CONTINUE

300   WRITE(NDEV,31)(JJ(KK),KK=11,20)
      WRITE(NDEV,311)

      DO 500 J=1,10
      SUM=0.
      DO 52 K=11,20
52    SUM=SUM+ASTAT(K,J)
      IF((J.GT.1).AND.(SUM.EQ.0.))GOTO 600
      WRITE(NDEV,222)(ASTAT(K,J),K=11,20)
500   CONTINUE

600   HZU=0
      DO 700 J=1,10
700   IF(TZU(J).NE.999.)HZU=J
      IF(HZU.EQ.0)GOTO 701
      WRITE(NDEV,223)(ZSTAT(J),J=1,10)
      WRITE(NDEV,224)(TZU(J),J=1,10)
701   WRITE(NDEV,225)(TREST(J),J=1,10)

      HZU=0
      DO 800 J=11,20
800   IF(TZU(J).NE.999.)HZU=J
      IF(HZU.EQ.0)GOTO 801
      WRITE(NDEV,223)(ZSTAT(J),J=11,20)
      WRITE(NDEV,224)(TZU(J),J=11,20)
801   WRITE(NDEV,225)(TREST(J),J=11,20)

      WRITE(NDEV,900)
900   FORMAT(3X,'-----------------------------------------------',
     1'--------------------------------')

      IF(NDEV.EQ.6)GOTO 1000
      WRITE(7,950)
950   FORMAT(1H$,'   AUSDRUCK AUF LP ?')
      READ(5,951)KLP
951   FORMAT(I3)
      IF(KLP.NE.1)GOTO 1000
      NDEV=6
      GOTO 100

1000  RETURN
      END


C     ****************************************************
C   1 UP EMOD , MODELLIERUNG DER LANDE-ENTSCHEIDUNG IM FINAL
C     ****************************************************

      SUBROUTINE EMOD(NST,TNEXT,E,DAUER)
C     ----------------------------------
      DIMENSION SL(21),SG(21),HL(21),HG(21),XM(2,2),HH(21)
      COMMON/HH/TOM,TDH,USI,USF,XGA,E1,E2,TE1,TE2,TFCH,TACH,TABR
      COMMON/F/XA,XB,XLAST,UBL(20)
      DATA (SL(J),J=1,21) /0.04,0.04,0.04,0.04,0.08,0.08,0.2,0.2,
     0.56,0.6,0.72,0.72,0.72,0.72,0.76,0.76,0.84,0.84,0.92,0.92,1.0/
      DATA (HL(J),J=1,21) /1.0,0.97,0.91,0.86,0.86,0.83,0.77,0.69,
     0.6,0.6,0.54,0.46,0.43,0.37,0.34,0.29,0.2,0.17,0.09,0.09,0.03/
      DATA (HG(J),J=13,21)/0.14,0.14,0.2,0.2,0.23,0.23,0.26,0.26,0.26/
      DATA (HH(J),J=1,21) /1300.,1200.,1100.,1000.,900.,800.,700.,600.,
     500.,400.,300.,200.,150.,100.,50.,0.,-50.,-100.,-150.,-200.,-300.

      KA=IFIX(XA)
```

Key: 1-specification of fuzzy eval. functions 2-predecision in step one has been taken? 3-determine present alt. and DH 4-determine difference between current and decision-alt. 5-determine present visibility 6-seek present visibility in fuzzy function 7-determine the evaluations for land/go around based on visibility 8-seek alt. difference in fuzzy function 9-determine evaluations for lang/go around based on altitude 10-fuzzy decision-making through min/max. calculation in the evaluation matrix

```
C      1 FESTLEGUNG DER FUZZY-BEWERTUNGSFUNKTIONEN:
C        ******************************************
C        (SL,HL,HG,HH SIEHE DATA-ANWEISUNG)
         SG(1)=0.16
         DO 1 J=2,21
1        SG(J)=0.
         DO 2 J=1,12
2        HG(J)=0.

C      2 VORENTSCHEIDUNG IN STUFE 1 GEFALLEN ?
C        ************************************
         IF(HST.EQ.1)GOTO 200
         IF(E1.EQ.0.)GOTO 200
         E=2.
         RETURN
200      CONTINUE
C      3 BESTIMMUNG DER AKTUELLEN HOEHE UND DER DH
C        *****************************************
         HR=(DAUER-TNEXT)*700./60.
         HE=(DAUER-TDH)*700./60.
C      4 BESTIMMUNG DER DIFFERENZ VON AKTUELLER ZUR ENTSCH.-HOEHE
         H=HR-HE

C      5 BESTIMMUNG DER AKTUELLEN SICHT
C        *****************************
         S=10.
         IF(NST.EQ.1)S=USF
         IF(NST.EQ.2)S=USI
C      6 AUFSUCHEN DER AKTUELLEN SICHT IN FUZZY-FUNKTION
C        **********************************************
         DO 8 J=1,21
         TS=(J-1)*0.5
         IF(S.LE.TS)GOTO 9
8        CONTINUE
9        J1=J
         DIFF=(TS-S)/0.5

C      7 BESTIMMUNG DER BEWERTUNGEN FUER LANDEN/GA AUFGRUND DER SICHT
C        ***********************************************************
         XM(1,1)=SL(J1)-(DIFF*(SL(J1)-SL(J1-1)))
         XM(1,2)=SG(J1)-(DIFF*(SG(J1)-SG(J1-1)))

C      8 AUFSUCHEN DER HOEHENDIFFERENZ IN FUZZY-FUNKTION
C        **********************************************
         DO 10 J=1,21
         TH=HH(J)
         IF(H.GE.TH)GOTO 11
10       CONTINUE
11       J1=J
         DIFF=(TH-H)/(HH(J1)-HH(J1-1))

C      9 BESTIMMUNG DER BEWERTUNGEN FUER LANDEN/GA AUFGRUND DER HOEHE
C        ***********************************************************
         XM(2,1)=HL(J1)-(DIFF*(HL(J1)-HL(J1-1)))
         XM(2,2)=HG(J1)-(DIFF*(HG(J1)-HG(J1-1)))

C     10 FUZZY-ENTSCHEIDUNGSFINDUNG DURCH MIN/MAX-RECHNUNG IN DER
C        BEWERTUNGSMATRIX
C        ********************************************************
         XLMIN=XM(1,1)
         IF(XM(2,1).LT.XLMIN)XLMIN=XM(2,1)
         XGMIN=XM(1,2)
         IF(XM(2,2).LT.XGMIN)XGMIN=XM(2,2)
         XMAX=XLMIN
         IF(XGMIN.GT.XMAX)XMAX=XGMIN
```

Key: 1-printout 2-decision for visibility voltage 3-and radar alt. 4-decision alt. 5-alt. difference 6-fuzzy eval. matrix for land/go around 7-determine the decision id. for the steps 8-statistical eval. of approaches from computer simulation 9-read in the input parameters

```
C       1 AUSDRUCK
C         ********
          IF(KA.EQ.2)PRINT 100,NST,S,HR,HE,H,XM(1,1),XM(1,2),XM(2,1),
          1XM(2,2),XLMIN,XGMIN
100       FORMAT(3X,'ENTSCHEIDUNGS-STUFE',I2,':',/,3X,
     2 -  1'ENTSCHEIDUNG BEI SICHT-SPANNUNG ',F8.2,' VOLT',/,3X,
     3    2'               UND RADAR-HOEHE ',F8.2,' FEET',//,3X,
     4    2'              ENTSCHEIDUNGSHOEHE ',F8.2,' FEET',//,3X,
     5    2'               HOEHEN-DIFFERENZ ',F8.2,' FEET',//,3X,
     6    3'FUZZY BEWERTUNGS-MATRIX FUER:      LANDEN     GO AROUND',/,3X,
          4'                                ',F8.2,'    ',F8.2,/,3X,
          4'                                ',F8.2,'    ',F8.2,/,3X,
          5'MINIMUM                         ',F8.2,'    ',F8.2,/)
          IF((XMAX.EQ.XLMIN).AND.(KA.EQ.2))PRINT 101,XMAX
          IF((XMAX.EQ.XGMIN).AND.(KA.EQ.2))PRINT 102,XMAX
101       FORMAT(3X,'LANDEN                          ',F8.2)
102       FORMAT(3X,'GO AROUND                       ',8X,'   ',F8.2)

C       7 BESTIMMUNG DER ENTSCHEIDUNGSKENNZIFFER FUER DIE STUFEN
C         ****************************************************
          IF(NST.EQ.2)GOTO 201
          IF(XMAX.EQ.XLMIN)E=1.
          IF(XMAX.EQ.XGMIN)E=0.
          GOTO 202
201       IF(XMAX.EQ.XLMIN)E=2.
          IF(XMAX.EQ.XGMIN)E=3.
202       CONTINUE

          RETURN
          END


C         **********************************************************
C         HP SIHIST , 8 STATISTISCHE AUSWERTUNG DER ANFLUEGE AUS RECHNER-
C                       SIMULATION
C         **********************************************************
          DIMENSION T(200),S1(200),S2(200),S3(200),S4(200),S5(200)
          DIMENSION TARR(50),TSER(50),TLEAV(50),TQUEU(50)
          DIMENSION TDAU(50)
          DIMENSION TA(15,50),TS(15,50),TL(15,50),TQ(15,50),TD(15,50)
          DIMENSION NAR(15),NSE(15),NLE(15),NQU(15),NDA(15)
          DIMENSION AT(20),DISZ(20),SER(20),SPA(20),SXQ(20),PBZ(20)
          DIMENSION HAR(15,25),HSE(15,25),HLE(15,25),HQU(15,25)
          DIMENSION HDA(15,25),HNFER1(15,25),HNFER2(15,25)
          DIMENSION HC1(25),HC2(25),XNLE1(28),XNDA1(28),NLE1(28),NDA1(28)
          DIMENSION XG(3),NNOTSE(15),NNOTSC(15)
          DIMENSION AAA(28),XSUM(20),BBB(50)
          COMMON /A/SU(20),SO(20),AU(20),AO(20)

          WRITE(7,1)
1         FORMAT(1H$,'   PHASE NR., ')
          READ(5,2)NPH
2         FORMAT(I4)
          NF2=NPH

C       9 EINLESEN VON EINGABEPARAMETERN
C         ****************************
          DEFINE FILE NF2(42,40,U,IVAR)
          READ(NF2'13)AT
          READ(NF2'17)DISZ
          READ(NF2'35)AU
          READ(NF2'36)AO
          READ(NF2'37)SU
          READ(NF2'38)SO
          READ(NF2'39)PBZ
          READ(NF2'40)NPH,IP1,IP2,PXQ,PVAR,PMIN,PMAX
          READ(NF2'41)SXQ
          READ(NF2'42)XSUM
```

Key: 1-read in already-calculated histogram values 2-no. of tests
3-test no. 4-read in the results from the computer simulation
5-processing loop for 15 tasks

```
      WRITE(7,8000)
8000  FORMAT(1H$,'    PMIN= ')
      READ(5,8100)PMIN
      WRITE(7,8200)
8200  FORMAT(1H$,'    PMAX= ')
      READ(5,8100)PMAX
8100  FORMAT(F20.10)
      NFF=30+NPH
      DEFINE FILE NFF(175,56,U,IVAR)
      DEFINE FILE 41(1500,104,U,IVAX)
      READ(41'1)BBB,XNNN,PPP

      WRITE(7,300)
300   FORMAT(1H$,'    FILE NR.: ')
      READ(5,2)NF
      DO 159 J=1,15
      DO 139 I=1,50
      TA(J,I)=-1.
      TS(J,I)=-1.
      TL(J,I)=-1.
      TQ(J,I)=-1.
      TD(J,I)=-1.
139   CONTINUE
159   CONTINUE
C   1 EINLESEN VON SCHON BERECHNETEN HISTOGRAMMWERTEN
C     ***********************************************
      CALL READR(NFF,15,0,HAR,NAR)
      CALL READR(NFF,15,15,HSE,NSE)
      CALL READR(NFF,15,30,HLE,NLE)
      CALL READR(NFF,15,45,HQU,NQU)
      CALL READR(NFF,15,60,HDA,NDA)
      CALL READR(NFF,15,115,HNFER1,NNOTSE)
      CALL READR(NFF,15,130,HNFER2,NNOISC)
      READ(NFF'108)HC1,XG
      READ(NFF'109)HC2,XG
      READ(NFF'146)XNLE1
      READ(NFF'147)XNDA1
      DO 750 NW=1,20
      NLE1(NW)=IFIX(XNLE1(NW))
      NDA1(NW)=IFIX(XNDA1(NW))
750   CONTINUE
310   CONTINUE

      DEFINE FILE NF(100,2400,U,IVAR)
      NVERS=IFIX(XG(1))
      NE10=0
      NE11=0
      NE22=0
      NE23=0                  2
      WRITE(7,733)
733   FORMAT(1H$,'    ANZAHL DER VERSUCHE: ')
      READ(5,734)KR
734   FORMAT(I4)
      DO 4 NNR=1,KR
      NVERS=NVERS+1           3
C     WRITE(7,871)
871   FORMAT(1H$,'    VERSUCH NR.: ')
C     READ(5,734)NR
      NR=NNR
C   4 EINLESEN DER ERGEBNISSE AUS DER RECHNERSIMULATION
C     *************************************************
      READ(NF'NR)T,S1,S2,S3,S4,S5
      NGES=IFIX(S3(41))
      TCM1=0.
      TCM2=0.
C   5 BEARBEITUNGSSCHLEIFE FUER 15 AUFGABEN
C     *************************************
      DO 50 NA=1,15
      DO 51 KP=1,50
      TARR(KP)=-1.
      TSER(KP)=-1.
      TLEAV(KP)=-1.
      TDAU(KP)=-1.
      TQUEU(KP)=-1.
51    CONTINUE
```

Key: 1-compute the times for arrival, beginning of execution, end of execution, waiting times, processing time

```
      NARR=0
      NSER=0
      NLEAV=0
      NLEAV2=0
      NLEAV3=0
      NQUEU=0
      NDAU=0
      NDAU2=0
      NBACK=0
      NDOPP=0
      NWARTE=0
      NN2=0
      NN3=0
      NZWI=0
      TTDAU=0.
      TTSER=0.
      TRUECK=0.
      AUF=FLOAT(NA)
      IF((AT(NA).LT.1.).OR.(AT(NA).GT.3.))GOTO 50
      DO 60 I=1,NGES
      IF(S2(I).EQ.0.)GOTO 61
      IF((AT(NA).EQ.3.).AND.(DISZ(IFIX(S2(I))).EQ.2.))NN2=1
      IF((AT(NA).EQ.3.).AND.(DISZ(IFIX(S1(I))).EQ.2.))NN3=1
61    GOTO(70,80,70)IFIX(AT(NA))
C
C     1 BERECHNUNG DER ZEITEN FUER AUFTRITTSZEITEN,
C       BEARBEITUNGSBEGINNN,BEARBEITUNGSENDE,WARTEZEITEN,
C       BEARBEITUNGSDAUER
C     ***********************************************
70    IF(NN2.NE.1)GOTO 81
      IF((NN3.EQ.1).AND.(S2(I).NE.AUF).AND.(S5(I).NE.S2(I)))GOTO 81
      GOTO 80
81    CALL ZEITEN(T,S1,S4,TCM1,DISZ,TARR,TSER,TLEAV,TQUEU,TDAU,
     1NARR,NSER,NLEAV,NQUEU,NDAU,I,AUF,TTSER,TTDAU,NDOPP,
     1TRUECK,NBACK,NWARTE,NLEAV2,NDAU2)
      GOTO 400
80    CALL ZEITEN(T,S2,S5,TCM2,DISZ,TARR,TSER,TLEAV,TQUEU,TDAU,
     1NARR,NSER,NLEAV,NQUEU,NDAU,I,AUF,TTSER,TTDAU,NDOPP,
     1TRUECK,NBACK,NWARTE,NLEAV2,NDAU2)
400   CONTINUE
      IF((NN2.EQ.1).AND.(S2(I).EQ.AUF))NN2=0
      IF((NN3.EQ.1).AND.(S1(I).EQ.AUF))NN3=0
60    CONTINUE
      IF(NARR.LT.1)GOTO 410
      DO 410 K=1,NARR
      IF(NPH.NE.3)GOTO 418
      IF(NA.NE.11)GOTO 415
      TARR(K)=S3(50)-TARR(K)
415   IF(NA.NE.12)GOTO 418
      TARR(K)=S3(52)-TARR(K)
418   TA(NA,K)=TARR(K)
410   CONTINUE
      IF(NSER.LT.1)GOTO 420
      DO 420 K=1,NSER
      TS(NA,K)=TSER(K)
420   CONTINUE
      IF(NLEAV.LT.1)GOTO 430
      DO 430 K=1,NLEAV
      TL(NA,K)=TLEAV(K)
430   CONTINUE
      IF(NQUEU.LT.1)GOTO 440
      DO 440 K=1,NQUEU
      TQ(NA,K)=TQUEU(K)
440   CONTINUE
      IF(NDAU.LT.1)GOTO 450
      DO 450 K=1,NDAU
      TD(NA,K)=TDAU(K)
450   CONTINUE
470   CONTINUE
      NNREC=(NR-1)*15+NA
      XNARR=FLOAT(NARR)
      WRITE(41'NNREC)TARR,XNARR,PMAX
      NAR(NA)=NAR(NA)+NARR
      NSE(NA)=NSE(NA)+NSER
      NLE(NA)=NLE(NA)+NLEAV
      NLE1(NA)=NLE1(NA)+NLEAV2
      NQU(NA)=NQU(NA)+NQUEU
      NDA(NA)=NDA(NA)+NDAU
      NDA1(NA)=NDA1(NA)+NDAU2
```

Key: 1-calculation of histograms 2-calculation of histograms for task-dependent simulation results 3-test I4 is finished!

```
C       1BERECHNUNG DER HISTOGRAMME
C        **************************
         IF((NA.NE.11).AND.(NA.NE.12))GOTO 416
         CALL HISTOG(NA,NARR,AU(NA),AO(NA),TA,HAR)
         GOTO 417
416      CALL HISTOG(NA,NARR,0.,PMAX,TA,HAR)
417      CALL HISTOG(NA,NSER,0.,PMAX,TS,HSE)
         CALL HISTOG(NA,NLEAV,0.,PMAX,TL,HLE)
         CALL HISTOG(NA,NQUEU,0.,PMAX,TQ,HQU)
         CALL HISTOG(NA,NDAU,SU(NA),SO(NA),TD,HDA)

         IF(NSER.LE.NARR)GOTO 935
         WRITE(6,939)NR,NA
939      FORMAT(//,3X,'VERSUCH NR.',I5,/,3X,'AUFGABE NR. '
        1,I5,/)
         DO 936 JX=1,NGES
         WRITE(6,937)T(JX),S1(JX),S2(JX),S4(JX),S5(JX)
937      FORMAT(3X,F20.4,4F7.0)
936      CONTINUE
935      CONTINUE
         NLEAV3=NLEAV+NLEAV2
         IF(NSER.LE.NLEAV3)GOTO 46
         GOTO(933,934,995)IFIX(AT(NA))
933      IF(S1(I-1).EQ.AUF)NNOTSE(NA)=NNOTSE(NA)+1
         NNOTSC(NA)=NNOTSC(NA)+NSER-NLEAV3
         IF(S1(I-1).EQ.AUF)NNOTSC(NA)=NNOTSC(NA)-1
         IF(S1(I-1).EQ.AUF)CALL HISTO3(NA,0.,SO(NA),S3(83),HNFER1)
         NSCH=0
         IF(S1(I-1).EQ.AUF)NSCH=1
         IF((NSER-NLEAV3-NSCH).LT.1)GOTO 1980
         DO 980 NG=1,(NSER-NLEAV3-NSCH)
         CALL HISTO3(NA,0.,SO(NA),S3(83),HNFER2)
980      CONTINUE
1980     CONTINUE
         GOTO 46
934      IF(S2(I-1).EQ.AUF)NNOTSE(NA)=NNOTSE(NA)+1
         NNOTSC(NA)=NNOTSC(NA)+NSER-NLEAV3
         IF(S2(I-1).EQ.AUF)NNOTSC(NA)=NNOTSC(NA)-1
         IF(S2(I-1).EQ.AUF)CALL HISTO3(NA,0.,SO(NA),S3(84),HNFER1)
         NSCH=0
         IF(S2(I-1).EQ.AUF)NSCH=1
         IF((NSER-NLEAV3-NSCH).LT.1)GOTO 1981
         DO 981 NG=1,(NSER-NLEAV3-NSCH)
         CALL HISTO3(NA,0.,SO(NA),S3(84),HNFER2)
981      CONTINUE
1981     CONTINUE
         GOTO 46
995      IF((S1(I-1).EQ.AUF).AND.(S2(I-1).EQ.AUF))NNOTSE(NA)=NNOTSE(NA)+1
         NNOTSC(NA)=NNOTSC(NA)+NSER-NLEAV3
         IF((S1(I-1).EQ.AUF).AND.(S2(I-1).EQ.AUF))NNOTSC(NA)=NNOTSC(NA)-1
         IF((S1(I-1).EQ.AUF).AND.(S2(I-1).EQ.AUF))
        1CALL HISTO3(NA,0.,SO(NA),S3(83),HNFER1)
         NSCH=0
         IF((S1(I-1).EQ.AUF).AND.(S2(I-1).EQ.AUF))NSCH=1
         IF((NSER-NLEAV3-NSCH).LT.1)GOTO 1982
         DO 982 NG=1,(NSER-NLEAV3-NSCH)
         CALL HISTO3(NA,0.,SO(NA),S3(83),HNFER2)
982      CONTINUE
1982     CONTINUE
46       CONTINUE
50       CONTINUE

         C1BUSY=TCM1/S3(42)
         C2BUSY=TCM2/S3(42)

C       2BERECHNUNG DER HISTOGRAMME FUER AUFGABENUNAB-
C        HAENGIGE SIMULATIONSERGEBNISSE
C        ***********************************************
         CALL HISTO2(0.,1.,C1BUSY,HC1)
         CALL HISTO2(0.,1.,C2BUSY,HC2)
         WRITE(7,102)NR
102      FORMAT(/,3X,'VERSUCH ',I4,' IST FERTIG!')3
4        CONTINUE
```

Key: 1-write the computer histogram values into the appropriate data files 2-statistical eval. of approaches from computer simulation, task-independent characteristic values 3-read in the input parameters

```
C       1 SCHREIBEN DER BERECHNETEN HISTOGRAMMWERTE IN DIE
C         ENTSPRECHENDEN DATENFILES
C         ************************************************
          CALL RECORD(NFF,15,0,HAR,NAR,0.,PMAX)
          CALL RECORD(NFF,15,15,HSE,NSE,0.,PMAX)
          CALL RECORD(NFF,15,30,HLE,NLE,0.,PMAX)
          CALL RECORD(NFF,15,45,HQU,NQU,0.,PMAX)
          CALL RECORD(NFF,15,60,HDA,NDA,1.,1.)
          CALL RECORD(NFF,15,115,HNFER1,NNOTSE,1.,1.)
          CALL RECORD(NFF,15,130,HNFER2,NNOTSC,1.,1.)
          XG(1)=FLOAT(NVERS)
          XG(2)=0.
          XG(3)=1.
          WRITE(NFF'108)HC1,XG
          WRITE(NFF'109)HC2,XG
          DO 751 NW=1,20
          XHLE1(NW)=FLOAT(NLE1(NW))
          XHDA1(NW)=FLOAT(NDA1(NW))
751       CONTINUE
          WRITE(NFF'146)XNLE1
          WRITE(NFF'147)XNDA1
999       CONTINUE
          STOP
          END

C         ****************************************************************
C       2 HP SIHIS2 , STATISTISCHE AUSWERTUNG DER ANFLUEGE AUS RECHNER-
C                     SIMULATION , AUFGABENUNABHAENGIGE KENNWERTE
C         ****************************************************************

          DIMENSION T(200),S1(200),S2(200),S3(200),S4(200),S5(200)
          DIMENSION AT(20),DISZ(20),SER(20),SPA(20),SXQ(20),PBZ(20)
          DIMENSION HAR(15,25)
          DIMENSION HEND(25),HDAUER(25),TARR(50),TZ(15,50),HZU(15,25)
          DIMENSION HTOH(25),HDH(25),HUSI(25),NZW(15)
          DIMENSION HUSF(25),HTE1(25),HTE2(25),XG(3)
          COMMON /A/SU(20),SO(20),AU(20),AO(20)

          WRITE(7,1)
1         FORMAT(1H$,'    PHASE NR.: ')
          READ(5,2)NPH
2         FORMAT(I4)
          NF2=NPH
C       3 EINLESEN VON EINGABEPARAMETERN
C         ******************************
          DEFINE FILE NF2(42,40,U,IVAR)
          DEFINE FILE 41(1500,104,U,IVAX)
          READ(NF2'35)AU
          READ(NF2'36)AO
          READ(NF2'37)SU
          READ(NF2'38)SO
          READ(NF2'39)PBZ
          READ(NF2'40)NPH,IP1,IP2,PXQ,PVAR,PMIN,PMAX
          READ(NF2'41)SXQ
          READ(NF2'42)XSUM
          DO 9350 KG=1,20
          AU(KG)=AU(KG)*60.
          AO(KG)=AO(KG)*60.
9350      CONTINUE
          PMIN=PMIN*60.
          PMAX=PMAX*60.
          WRITE(7,8000)
8000      FORMAT(1H$,'    PMIN= ')
          READ(5,8100)PMIN
8100      FORMAT(F20.10)
          WRITE(7,8200)
8200      FORMAT(1H$,'    PMAX= ')
          READ(5,8100)PMAX
```

Key: 1-read in already-calculated histogram values 2-no. of tests
3-test no. 4-read in the results of the computer simulation
5-compute histograms for task-independent simulation results
6-the following values only appear in phase 3

```
      NFF=30+NPH
      DEFINE FILE NFF(175,56,U,IVAR)
      WRITE(7,300)
300   FORMAT(1H$,'   FILE NR.: ')
      READ(5,2)NF

C    1EINLESEN VON SCHON BERECHNETEN HISTOGRAMMWERTEN
C     ************************************************
      READ(NFF'106)HEND,XG
      READ(NFF'107)HDAUER,XG
      READ(NFF'110)HTOM,XG
      READ(NFF'111)HDH,XG
      READ(NFF'112)HUSI,XG
      READ(NFF'113)HUSF,XG
      READ(NFF'114)HTE1,XG
      READ(NFF'115)HTE2,XG
      CALL READR(NFF,15,90,HZW,HZW)
310   CONTINUE

      DEFINE FILE NF(100,2400,U,IVAR)
      NVERS=IFIX(XG(1))
      NE10=0
      NE11=0
      NE22=0
      NE23=0
      WRITE(7,733)      2
733   FORMAT(1H$,'   ANZAHL DER VERSUCHE: ')
      READ(5,734)KR
734   FORMAT(I4)
      DO 4 NNR=1,KR
      NVERS=NVERS+1
C     WRITE(7,871)    3
871   FORMAT(1H$,'   VERSUCH NR.: ')
C     READ(5,734)NR
      NR=NNR

C    4 EINLESEN DER ERGEBNISSE AUS DER RECHNERSIMULATION
C     **************************************************
      READ(NF'NR)T,S1,S2,S3,S4,S5
      NGES=IFIX(S3(41))

C    5BERECHNUNG DER HISTOGRAMME FUER AUFGABENUNAB-
C     HAENGIGE SIMULATIONSERGEBNISSE
C     ************************************************
      CALL HISTO2(0.,PMAX,S3(42),HEND)
      CALL HISTO2(0.,PMAX,S3(50),HDAUER)
      IF(NPH.NE.3)GOTO 200

C    6FOLGENDE WERTE TRETEN NUR IN PHASE 3 AUF
C     ----------------------------------------
      TTOM=S3(50)-S3(51)
      TTDH=S3(50)-S3(52)
      CALL HISTO2(52.,130.,TTOM,HTOM)
      CALL HISTO2(20.,100.,TTDH,HDH)
      CALL HISTO2(0.,10.,S3(53),HUSI)
      CALL HISTO2(0.,10.,S3(54),HUSF)
      CALL HISTO2(0.,PMAX,S3(58),HTE1)
      CALL HISTO2(0.,PMAX,S3(59),HTE2)
      IF(S3(56).EQ.0.)NE10=NE10+1
      IF(S3(56).EQ.1.)NE11=NE11+1
      IF(S3(57).EQ.2.)NE22=NE22+1
      IF(S3(57).EQ.3.)NE23=NE23+1
200   CONTINUE
      DO 2000 NA=1,15
      IF(NPH.NE.3)GOTO 201
      IF((NA.EQ.11).OR.(NA.EQ.12))GOTO 2000
201   NNREC=(NR-1)*15+NA
      READ(41'NNREC)TARR,XNARR,PMURKS
      NARR=IFIX(XNARR)
      IF((NARR.LT.1).OR.(NARR.EQ.999))GOTO 2001
      IF(PBZ(NA).EQ.1.)GOTO 2001
      TZ(NA,1)=TARR(1)
      IF(NARR.LT.2)GOTO 2002
      DO 2002 NJ=2,NARR
      NT=NJ
      TZ(NA,NT)=TARR(NT)-TARR(NT-1)
2002  CONTINUE
```

Key: 1-write the computed histogram values in the appropriate data files 2-statistical eval., tabular output + histogram

```
      NZWI=NARR
      NZW(NA)=NZW(NA)+NZWI
      CALL HISTOG(NA,NZWI,AU(NA),AO(NA),TZ,HZW)
2001  CONTINUE
2000  CONTINUE
      WRITE(7,102)NR
102   FORMAT(/,3X,'VERSUCH ',I4,' IST FERTIG!')
4     CONTINUE
C
C    1SCHREIBEN DER BERECHNETEN HISTOGRAMMWERTE IN DIE
C     ENTSPRECHENDEN DATENFILES
C     ***********************************************
      CALL RECORD(NFF,15,90,HZW,NZW,1.,1.)
      XG(1)=FLOAT(NVERS)
      XG(2)=0.
      XG(3)=PMAX
      WRITE(NFF'106)HEND,XG
      WRITE(NFF'107)HDAUER,XG
      WRITE(NFF'114)HTE1,XG
      WRITE(NFF'115)HTE2,XG
      XG(2)=52.
      XG(3)=130.
      WRITE(NFF'110)HTOM,XG
      XG(2)=28.
      XG(3)=100.
      WRITE(NFF'111)HDH,XG

      XG(2)=0.
      XG(3)=10.
      WRITE(NFF'112)HUSI,XG
      WRITE(NFF'113)HUSF,XG
      IF(NPH.NE.3)GOTO 999
      WRITE(6,310)
310   FORMAT(3X,'ANZAHL VON',//,5X,'E1=0      E1=1      E2=2      E2=3')
      WRITE(6,311)NE10,NE11,NE22,NE23
311   FORMAT(/,4I9)
999   CONTINUE

      STOP
      END


C     ********************************************************
C    2HP SIZEI , STAT.AUSWERTUNG: TABELLENAUSDRUCK + HISTOGRAMME
C     ********************************************************

      DIMENSION H(25),W(25),A(108),H1(25)
      DIMENSION XG(3),XMI(16,10),XMA(16,10),XQUE(16,10)
      DIMENSION SIGM(16,10),NANZ(16,10)
      DIMENSION NLE1(28),NDA1(28),NLND(28)
      DIMENSION XNLE1(28),XNDA1(28)
      COMMON /STAT/X(2000),Y(2000),IX(2000)
      DATA A/'AUFT','RITT','SZEI','T   ','    ','BEAR','BEIT',
     1'UNGS','BEGI','NN  ','BEAR','BEIT','UNGS','ENDE','    ',
     1'WART','EZEI','T   ','    ','    ','BEAR','BEIT','UNGS',
     1'DAUE','R   ','REST','ZEIT',' (NI','CHT ','B.) ','ZWIS',
     1'CHEN','ZEIT','    ','    ','SIMU','LATI','ONSE','NDE ',
     1'    ','PHAS','ENDA','UER ','    ','    ','AUSL','ASTU',
     1'NG C','M1  ','    ','AUSL','ASTU','NG C','M2  ','    ',
     1'UEBE','RFLU','G OM','    ','    ','ZEIT',' BEI',' D.H',
     1'.   ','    ','SICH','T BE','I D.','H.  ','    ','SICH',
     1'T BE','I F.','I.S.','    ','ZEIT','PUNK','T E1','    ',
     1'    ','ZEIT','PUNK','T E2','    ','    ','(*) ','T  (',
     1'**) ','REST','Z. (','H. F','. I.',' SE)','REST','Z. (',
     1'H. F','. I.',' SL)','ENDE',' (TE','IL) ','    ','    ',
     1'DAUE','R (T','EIL)','    ','    '/
```

Key: 1-test series no. 2-no. of tests 3-read the histogram values from data file 4-no value present 5-compute ordinate and abscissa

```
      DO 200 JU=1,2000
      X(JU)=0.
      Y(JU)=0.
      IX(JU)=0
200   CONTINUE
      DO 201 JU=1,16
      DO 202 JW=1,10
      XMI(JU,JW)=0.
      XMA(JU,JW)=0.
      XQUE(JU,JW)=0.
      SIGM(JU,JW)=0.
      HANZ(JU,JW)=0
202   CONTINUE
201   CONTINUE
      WRITE(7,8)      1
8     FORMAT(1H$,'    VERSUCHSREIHE NR.: ')
      READ(5,2)NVR
      WRITE(7,1)
1     FORMAT(1H$,'    PHASE NR.: ')
      READ(5,2)NPH
      WRITE(7,99)    2
99    FORMAT(1H$,'    ANZAHL DER VERSUCHE: ')
      READ(5,2)NVER
2     FORMAT(I5)
      NFF=30+NPH
      DEFINE FILE NFF(175,56,U,IVAR)
      DO 11 JZ=1,15

      DO 10 J=1,9
      IF(J.EQ.6)GOTO 10
      ZONG=0.
      NREC=(J-1)*15+JZ
      IF(J.EQ.8)NREC=115+JZ
      IF(J.EQ.9)NREC=130+JZ

C   3 LESEN DER HISTOGRAMMWERTE AUS DATENFILE
C     ****************************************
      READ(NFF'NREC)H1,XG
      IF(XG(1).NE.0.)GOTO 90          4
      WRITE(7,91)
91    FORMAT(3X,'KEIN WERT VORHANDEN!')
      GOTO 10
90    CONTINUE
      DO 6 JJ=1,25
      ZONG=ZONG+H1(JJ)
6     W(JJ)=0.
      HANZ(JZ,J)=IFIX(XG(1))
      XMIN=XG(2)
      XMAX=XG(3)
      XMI(JZ,J)=XMIN
      XMA(JZ,J)=XMAX
      DIFF=(XMAX-XMIN)/24.
      IF(ZONG.NE.0.)GOTO 6500
      WRITE(6,4600)NREC,XMIN,XMAX,IFIX(XG(1))
      GOTO 10
6500  CALL NORMI(H1,DIFF,XG(I),H)

C   5 BERECHNUNG VON ORDINATE UND ABSZISSE
      XQUER=0.
      SIGMA=0.
      DO 7 JJ=1,25
      W(JJ)=XMIN+(JJ-1)*DIFF
      XQUER=XQUER+H(JJ)*W(JJ)*DIFF
7     CONTINUE
      DO 17 JJ=1,25
      SIGMA=SIGMA+H(JJ)*DIFF*(W(JJ)-XQUER)**2
      XQUE(JZ,J)=XQUER
      SIGM(JZ,J)=SIGMA
17    CONTINUE
100   CONTINUE
10    CONTINUE
11    CONTINUE
```

Key: 1-printout of results table 2-test series no. 3-no. of tests 4-task no.

```
      DO 70 LL=106,115
      ZONG=0.
      J=LL-105
      IF((LL.GT.109).AND.(NPH.NE.3))GOTO 891
      NREC=LL
      K=(LL-106)*5+30
      READ(NFF'NREC)H1,XG
      IF(XG(1).NE.0.)GOTO 92
      WRITE(7,91)
      GOTO 70
92    CONTINUE
      DO 3300 JJ=1,25
      ZONG=ZONG+H1(JJ)
3300  W(JJ)=0.
      NANZ(16,J)=IFIX(XG(1))
      XMIN=XG(2)
      XMAX=XG(3)
      XMI(16,J)=XMIN
      XMA(16,J)=XMAX
      DIFF=(XMAX-XMIN)/24.
      XXX=XG(1)
4600  FORMAT(3X,'REC  ',I4,'MIN ',F12.5,'MAX ',F12.5,'N= ',I5)
4500  IF(XMAX.NE.XMIN)GOTO 4300
      WRITE(7,4400)XMIN,XMAX
4400  FORMAT(3X,'XMIN= ',F15.5,3X,'XMAX= ',F15.5)
      GOTO 70
4300  CALL NORMI(H1,DIFF,XXX,H)
      XQUER=0.
      SIGMA=0.
      DO 307 JJ=1,25
      W(JJ)=XMIN+(JJ-1)*DIFF
      XQUER=XQUER+H(JJ)*W(JJ)*DIFF
307   CONTINUE
      DO 37 JJ=1,25
      SIGMA=SIGMA+H(JJ)*DIFF*(W(JJ)-XQUER)**2
37    CONTINUE
      XQUE(16,J)=XQUER
      SIGM(16,J)=SIGMA
891   CONTINUE
70    CONTINUE
987   CONTINUE                  1
      WRITE(7,560)
560   FORMAT(1H$,'   AUSDRUCK DER ERGEBNISTABELLE ? ')
      READ(5,2)NTAB
      IF(NTAB.NE.1)GOTO 561
      READ(NFF'146)XNLE1
      READ(NFF'147)XNDA1
      DO 750 NW=1,28
      NLE1(NW)=IFIX(XNLE1(NW))
      NDA1(NW)=IFIX(XNDA1(NW))
750   CONTINUE
      PRINT 550,NVR,NPH,NVER          2
550   FORMAT(//,3X,'VERSUCHSREIHE NR.  ',I3,5X,'PHASE NR.  ',I3,
     15X,'ANZAHL DER VERSUCHE: ',I5)
      PRINT 551                        3
551   FORMAT(3X,'------------------------------------------
     1-----------------------------------------')
      PRINT 552   4
552   FORMAT(3X,'AUFG. NR.  I      PARAMETER        I   NGES   I
     1   XMIN   I   XMAX   I   XQUER I  SIGMA  ')
      PRINT 551
      DO 553 JTA=1,15
      IF(NANZ(JTA,1).EQ.0)GOTO 553
      DO 554 JTB=1,9
      IF(JTB.EQ.6)GOTO 554
      JTU=JTB
      IF(JTB.EQ.7)JTU=8
      IF(JTB.EQ.8)JTU=9
      IF(JTB.EQ.9)JTU=7
      K=(JTU-1)*5
      IF(JTU.EQ.8)K=88
      IF(JTU.EQ.9)K=93
      IF(JTU.EQ.3)K1=98
      IF(JTU.EQ.5)K1=103
```

Key: 1-no value calc. 2-rel. to time at DH 3-draw histograms? 4-draw histogram of task 5-or task independent 6-command 7-arrival time 8-begin processing 9-end processing 10-waiting time 11-processing duration 12-interarrival time 13-simulation end 14-workload on CM1

```
      IF(JTU.EQ.3)NLND(JTA)=NLE1(JTA)
      IF(JTU.EQ.5)NLND(JTA)=NDA1(JTA)
      IF(JTU.NE.1)GOTO 791
      IF(NPH.NE.3)GOTO 791
      IF((JTA.NE.11).AND.(JTA.NE.12))GOTO 791
      IF(JTA.EQ.11)PRINT 555,JTA,A(K+1),A(K+2),A(K+3),A(K+4),A(86)
     1,NANZ(JTA,JTU),XMI(JTA,JTU),XMA(JTA,JTU),XQUE(JTA,JTU)
     1,SIGM(JTA,JTU)
      IF(JTA.EQ.12)PRINT 555,JTA,A(K+1),A(K+2),A(K+3),A(87),A(88)
     1,NANZ(JTA,JTU),XMI(JTA,JTU),XMA(JTA,JTU),XQUE(JTA,JTU)
     1,SIGM(JTA,JTU)
      GOTO 792
791   PRINT 555,JTA,A(K+1),A(K+2),A(K+3),A(K+4),A(K+5),NANZ(JTA,JTU)
     1,XMI(JTA,JTU),XMA(JTA,JTU),XQUE(JTA,JTU),SIGM(JTA,JTU)
792   CONTINUE
555   FORMAT(I8,4X,'I ',5A4,' I',I6,'   I',F8.2,' I',F8.2,' I',
     1F8.2,' I',F8.2)
      IF((JTU.EQ.3).OR.(JTU.EQ.5))PRINT 5000,JTA,A(K1+1),A(K1+2),
     1A(K1+3),A(K1+4),A(K1+5),NLND(JTA)
5000  FORMAT(I8,4X,'I ',5A4,' I',I6,'   I',9X,'KEINE WERTBERECHNUNG')1
554   CONTINUE
      PRINT 551
553   CONTINUE
      PRINT 556
556   FORMAT(35X,'I',9X,'I',9X,'I',9X,'I',9X,'I')
      PRINT 551
      PRINT 556
      DO 558 JTU=1,10
      IF(NANZ(16,JTU).EQ.0)GOTO 558
      K=(JTU-1)*5+35
      IF((JTU.NE.5).AND.(JTU.NE.6))GOTO 796
      PRINT 557,A(K+1),A(K+2),A(K+3),A(K+4),A(86),NANZ(16,JTU)
     1,XMI(16,JTU),XMA(16,JTU),XQUE(16,JTU),SIGM(16,JTU)
      GOTO 797
796   PRINT 557,A(K+1),A(K+2),A(K+3),A(K+4),A(K+5),NANZ(16,JTU)
     1,XMI(16,JTU),XMA(16,JTU),XQUE(16,JTU),SIGM(16,JTU)
797   CONTINUE
557   FORMAT(14X,5A4,' I',I6,'   I',F8.2,' I',F8.2,' I',
     1F8.2,' I',F8.2)
558   CONTINUE
561   CONTINUE
2500  CONTINUE
      IF(NPH.EQ.3)PRINT 798                                      2
798   FORMAT(///,7X,'*   BEZOGEN AUF PHASENENDE',/,6X,'**   BEZOGEN
     1 AUF ZEIT BEI D.H.')
      WRITE(7,1000)                        3
1000  FORMAT(1H$,'   ZEICHNEN VON HISTOGRAMMEN ? ')
      READ(5,2)NZEI
      IF(NZEI.NE.1)GOTO 2000
      WRITE(7,4)                                         4
4     FORMAT(//,3X,'ZEICHNEN DES HISTOGRAMMS VON AUFGABE (1-15)
     1',/,3X,'ODER AUFGABENUNABHAENGIG (16)',//,1H$,'   BEFEHL : ')
                                     5                       6
      READ(5,2)NSTR
      IF((NSTR.LT.1).OR.(NSTR.GT.16))GOTO 2100
      IF(NSTR.EQ.16)GOTO 115
      WRITE(7,5)                  7
5     FORMAT(//,3X,'AUFTRITTSZEIT          1',/,3X,       9
  8 - 1'BEARBEITUNGSBEGINN   2',/,3X,'BEARBEITUNGSENDE  11  3',/,3X,
 10 - 1'WARTEZEIT            4',/,3X,'BEARBEITUNGSDAUER     5',/,3X,
     1'RESTZ. (N.F. I. SE) 6',/,3X,'RESTZ. (N.F. I. SL) 7',/,3X,
     1'ZWISCHENZEIT 12     8')
      GOTO 120                       13
115   WRITE(7,150)
150   FORMAT(//,3X,'SIMULATIONSENDE      1',/,3X,
     1'PHASENDAUER          2',/,3X,'AUSLASTUNG CM1         3',/,3X,
     1'AUSLASTUNG CM2       4')           14
      IF(NPH.NE.3)GOTO 120
      WRITE(7,151)
151   FORMAT(3X,'UEBERFLUG OM           5',/,3X,
     1'ZEIT BEI D.H.        6',/,3X,'SICHT BEI D.H.         7',/,3X,
     1'SICHT BEI F.I.S.     8',/,3X,'ZEITPUNKT E1           9',/,3X,
     1'ZEITPUNKT E2        10')
120   WRITE(7,121)
121   FORMAT(1H$,'   PARAMETER : ')
```

Key: 1-scale determination 2-scale factor 3-change 4-new value

```
      READ(5,2)NPAR
      NREC=(NPAR-1)*15+NSTR
      IF(NPAR.EQ.6)NREC=115+NSTR
      IF(NPAR.EQ.7)NREC=130+NSTR
      IF(NPAR.EQ.8)NREC=90+NSTR
      IF(NSTR.EQ.16)NREC=NPAR+105
      READ(NFF'NREC)H1,XG
      IF(XG(1).NE.0.)GOTO 9200
      WRITE(7,91)
      GOTO 70
9200  CONTINUE
      DO 306 JJ=1,25
306   W(JJ)=0.
      NANZ(16,J)=IFIX(XG(1))
      XMIN=XG(2)
      XMAX=XG(3)
      XMI(16,J)=XMIN
      XMA(16,J)=XMAX
      DIFF=(XMAX-XMIN)/24.
      CALL NORMI(H1,DIFF,XG(1),H)
      L1=25
      DO 20 L=1,25
      XL=FLOAT(L-1)
      Y(L)=-(-10+XL*0.8)
      IF(Y(L).GT.-10.)GOTO 20
      L1=L
      GOTO 25
20    CONTINUE
25    CONTINUE

C    1 MASSTABSBESTIMMUNG

      XMASS=0.0001    2                  3
      WRITE(7,30)
30    FORMAT(3X,'MASSTABSFAKTOR 0.0001. AENDERN? ')
      READ(5,2)KAEN
      IF(KAEN.NE.1)GOTO 31
      WRITE(7,32)                  4
32    FORMAT(1H$,'    NEUER WERT: ')
      READ(5,33)XMASS
33    FORMAT(F20.10)
31    CONTINUE
      HMAX=H(1)
      DO 600 L=1,25
      X(L)=H(L)
      IF(X(L).GT.HMAX)HMAX=X(L)
600   CONTINUE

      CALL ZEICHA(2,1,L1,XMASS,0.004)
2100  GOTO 2500
2000  CONTINUE
      END


C     ************
C     UP READR.FOR
C     ************

      SUBROUTINE READR(NFF,NREC,NPLUS,H,N)
C     ------------------------------------
      DIMENSION H(15,25),A(25),N(15),XG(3)

      DO 10 J=1,NREC

      READ(NFF'(J+NPLUS))A,XG
      N(J)=IFIX(XG(1))
      DO 20 K=1,25
      H(J,K)=A(K)
20    CONTINUE
10    CONTINUE
      RETURN
      END
```

```
C       *************
C       UP RECORD.FOR
C       *************

        SUBROUTINE RECORD(NFF,NREC,NPLUS,H,N,XMIN,XMAX)
C       ------------------------------------------------
        DIMENSION H(15,25),A(25),N(15),XG(3)
        COMMON /A/SU(20),SO(20),AU(20),AO(20)
        DO 10 J=1,NREC
        DO 20 K=1,25
        A(K)=H(J,K)
 20     CONTINUE
        IF(NPLUS.EQ.60)XG(2)=SU(J)
        IF((NPLUS.EQ.75).OR.(NPLUS.EQ.115).OR.(NPLUS.EQ.130))XG(2)=0.
        IF((NPLUS.EQ.60).OR.(NPLUS.EQ.75).OR.(NPLUS.EQ.115))XG(3)=SO(J)
        IF(NPLUS.EQ.130)XG(3)=SO(J)
        IF(NPLUS.EQ.90)XG(2)=AU(J)
        IF(NPLUS.EQ.90)XG(3)=AO(J)
        XG(1)=FLOAT(N(J))
        IF((NPLUS.EQ.60).OR.(NPLUS.EQ.75).OR.(NPLUS.EQ.90))GOTO 50
        IF((NPLUS.EQ.115).OR.(NPLUS.EQ.130))GOTO 50
        XG(2)=XMIN
        XG(3)=XMAX
        IF((NPLUS.EQ.0).AND.(NFF.EQ.33).AND.(J.EQ.11))XG(2)=AU(J)
        IF((NPLUS.EQ.0).AND.(NFF.EQ.33).AND.(J.EQ.11))XG(3)=AO(J)
        IF((NPLUS.EQ.0).AND.(NFF.EQ.33).AND.(J.EQ.12))XG(2)=AU(J)
        IF((NPLUS.EQ.0).AND.(NFF.EQ.33).AND.(J.EQ.12))XG(3)=AO(J)
 50     CONTINUE
        WRITE(NFF'(J+NPLUS))A,XG
 10     CONTINUE
        RETURN
        END


C       *************
C       UP ZEITEN.FOR
C       *************

        SUBROUTINE ZEITEN(T,S1,S4,TCM,DISZ,TARR,TSER,TLEAV,TQUEU,
       1TDAU,NARR,NSER,NLEAV,NQUEU,NDAU,I,AUF,TTSER,TTDAU,NDOPP
       1,TRUECK,NBACK,NWARTE,NLEAV2,NDAU2)
C       ---------------------------------------------------------
        DIMENSION T(200),S1(200),S4(200),TARR(50),TSER(50)
        DIMENSION TLEAV(50),TQUEU(50),TDAU(50)
        DIMENSION DISZ(20)

        NA=IFIX(AUF)
        IF(S4(I).NE.AUF)GOTO 120
        NARR=NARR+1
        NWARTE=NWARTE+1
        TARR(NARR)=T(I)
        IF((DISZ(NA).NE.2.).AND.(S1(I).EQ.AUF))GOTO 140
 120    IF(S1(I).NE.AUF)GOTO 140
        IF(I.EQ.1)GOTO 125
        IF((S1(I).EQ.S1(I-1)).AND.(S4(I).NE.AUF))GOTO 150
        IF((S1(I).EQ.S1(I-1)).AND.(S4(I).EQ.AUF).AND.(DISZ(NA).EQ.
       12.))GOTO 250
        GOTO 125
 250    NDOPP=1
        GOTO 175
        IF(S1(I).EQ.S1(I-1))GOTO 150
 125    IF(NBACK.EQ.0)GOTO 155
        IF(NBACK.NE.1)GOTO 163
        TTSER=T(I)
        NQUEU=NQUEU+1
        TQUEU(NQUEU)=TTSER-TRUECK
 163    IF(DISZ(NA).NE.2.)GOTO 165
        IF((S1(I).EQ.S4(I)).AND.(NBACK.GT.0).AND.(S1(I).EQ.AUF))
       1GOTO 185
 165    CONTINUE
        NBACK=NBACK-1
        GOTO 160
```

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185     NWARTE=NWARTE-1
        NBACK=NBACK-1
        NLEAV2=NLEAV2+1
        NDAU2=NDAU2+1
358     CONTINUE
        IF((S1(I).EQ.AUF).AND.(DISZ(NA).EQ.2.).AND.(S4(I).NE.AUF))
       1GOTO 900
155     NSER=NSER+1
        TSER(NSER)=T(I)
        TTSER=TSER(NSER)
900     CONTINUE
        NQUEU=NQUEU+1
        TQUEU(NQUEU)=TSER(NSER)-TARR(NSER)
        IF(TQUEU(NQUEU).EQ.0.)NQUEU=NQUEU-1
        IF(NWARTE.EQ.0)TQUEU(NQUEU)=0.
160     NWARTE=NWARTE-1
        IF(NWARTE.LT.0)NWARTE=0
140     IF(I.EQ.1)GOTO 190
        IF(NDOPP.NE.1)GOTO 143
        NDOPP=0
        GOTO 150
143     IF((S1(I).NE.AUF).AND.(S1(I-1).EQ.AUF))GOTO 146
        IF((S1(I).EQ.AUF).AND.(S1(I-1).EQ.AUF).AND.(DISZ(NA).EQ.2.)
       1)GOTO 175
        GOTO 190
146     IF(S1(I).EQ.0.)GOTO 175
        IF(DISZ(IFIX(S1(I))).NE.2.)GOTO 175
        IF(S1(I-1).EQ.0.)GOTO 175
        NBACK=NBACK+1
        NWARTE=NWARTE+1
        IF(NBACK.GT.1)GOTO 171
        TRUECK=T(I)
        TTDAU=TTDAU-TTSER+TRUECK
171     GOTO 180
175     NLEAV=NLEAV+1
        TLEAV(NLEAV)=T(I)
        NDAU=NDAU+1
        TDAU(NDAU)=TLEAV(NLEAV)-TTSER+TTDAU
        TTDAU=0.
        TCM=TCM+TDAU(NDAU)
        IF(NDOPP.EQ.1)GOTO 358
150     CONTINUE
190     CONTINUE
180     CONTINUE
        RETURN
        END


C       *************
C       UP HISTOG.FOR
C       *************

        SUBROUTINE HISTOG(NA,N,XMIN,XMAX,B,H)
C       ----------------------------------
        DIMENSION B(15,50),H(15,25)
        IF(N.EQ.0)GOTO 10
        DIFF=(XMAX-XMIN)/24.
        DO 10 J=1,N
        DO 20 K=1,25
        XU=XMIN+(K-1)*DIFF
        XO=XU+DIFF
        IF((B(NA,J).GE.XU).AND.(B(NA,J).LT.XO))H(NA,K)=H(NA,K)+1.
20      CONTINUE
10      CONTINUE
        RETURN
        END
```

```
C       *************
C       UP HISTO2.FOR
C       *************

        SUBROUTINE HISTO2(XMIN,XMAX,B,H)
C       --------------------------------
        DIMENSION H(25)
        IF(B.EQ.0.)GOTO 10
        DIFF=(XMAX-XMIN)/24.
        DO 10 K=1,25
        XU=XMIN+(K-1)*DIFF
        XO=XU+DIFF
        IF((B.GE.XU).AND.(B.LT.XO))H(K)=H(K)+1.
10      CONTINUE

        RETURN
        END
```

```
C       *************
C       UP HISTO3.FOR
C       *************

        SUBROUTINE HISTO3(NA,XMIN,XMAX,B,H)
C       -----------------------------------
        DIMENSION H(15,25)
        IF(B.EQ.0.)GOTO 10
        DIFF=(XMAX-XMIN)/24.
        DO 10 K=1,25
        XU=XMIN+(K-1)*DIFF
        XO=XU+DIFF
        IF((B.GE.XU).AND.(B.LT.XO))H(NA,K)=H(NA,K)+1.
10      CONTINUE

        RETURN
        END
```

```
C       ************
C       UP NORMI.FOR
C       ************

        SUBROUTINE NORMI(H1,DIFF,XSUM,H)
C       --------------------------------
        DIMENSION H1(25),H(25)

        F=0.
        DO 1 J=1,25
        F=F+H1(J)*DIFF
1       CONTINUE

        DO 2 J=1,25
        H(J)=H1(J)/F
2       CONTINUE

        RETURN
        END
```

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