Communications

Operational Sequence Diagrams*

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A new method has been evolved to facilitate development of the more complex weapon systems by providing concurrently with the design of the system a clear definition of contemplated man-machine relationships. In its present form, this method was employed successfully on the Sparrow III, Hawk, TAC-BADGE Polaris, Thor, Swallow, and other missile system programs. The technique provides a schematic diagram of the essential interactions among operators, stations, equipments, and time. Design flaws in the system, either from an equipment or operator point of view, are revealed by the schematic or decision-action flow chart which we will call an Operational Sequence Diagram (OSD). These diagrams present graphically the interactions between man and machines. The OSD reveals system weaknesses that can be directly traced to inadequate hardware or communication-link construction. In addition, the OSD provides a realistic description of system operation which enables the human factors man to design consoles and arrange panels.

Consider the use of OSD during the design of a hypothetical air-launched ballistic missile (ALBM) weapon system composed of the following major subsystems: fire control, launcher, aircraft, navigation, missile (including missile checkout) and communications. Assume that four men will perform all necessary operations for launch, and that the subsystems will be assigned in the following manner: pilot—aircraft and command; navigator—communications and navigation; flight engineer—launcher and missile; co-pilot—fire control.

As soon as the equipment units have been defined, the first draft of an OSD should be attempted. At this stage, the diagram might appear as in Fig. 1. Individual consoles are grouped as subcolumns under major columns corresponding to each operator. Since the assumption has been made that the co-pilot will perform fire control functions and thus coordinate all launch activities, the central columns on the diagram represent the co-pilot's activities and decisions during countdown procedures. To the left of the operator-equipment columns, an estimate has been made of the relative time each operator or equipment action will take prior to launch (note that this hypothetical system employs four inertially guided solid-fuel missiles and that the weapons carrier has the capability of rapid successive launch at different targets).

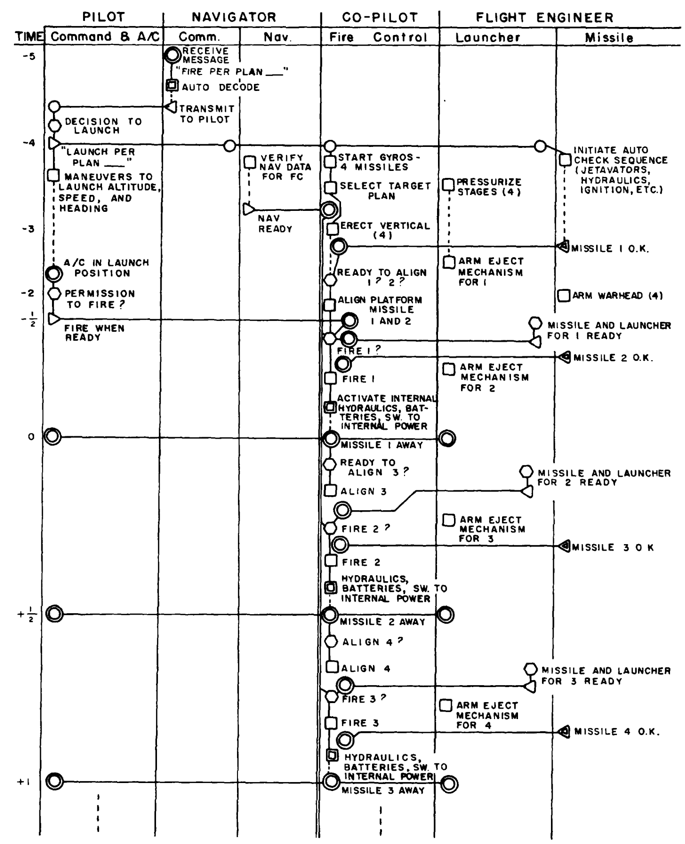

Fig. 1—An example of an Operational Sequence Diagram.

Squares on the diagram are used to indicate actions; automatic or machine operations are indicated by double outline squares, manual actions by single outline squares; hexagons represent operator decisions. Triangles are used to indicate the transmission of information, and circles are used to indicate the receipt of information. A double circle indicates, for example, activation of an indicator light by a remote action. Single circles represent receipt of information by manual (verbal or written) means. Wherever quantities necessary for normal operation have not been specified (or rely upon external sources), a dash can be used to indicate a required quantity that must be furnished. Fig. 2 summarizes OSD symbols and rules that have proven successful.

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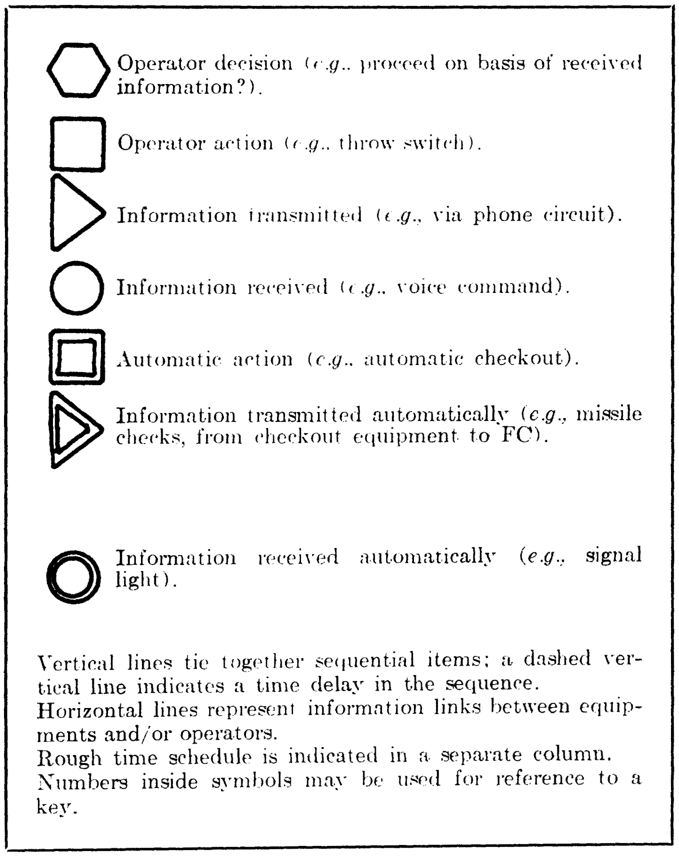

Fig. 2—Symbols and rules for construction of Operational Sequence Diagrams.

Numbers within a block refer to a key where a more extensive discussion may be provided. Note that on the diagram only enough words or abbreviations are provided to identify a particular item. A compact, concise diagram is necessary if someone besides the originator is ever to study it. At a glance, it should be possible to determine if the preliminary allocation of duties has been equitable. System inconsistencies often show up in an OSD that might otherwise have gone undetected until the completed system was airborne and under test and evaluation. Changes at the latter time are usually extremely expensive, both in dollars and in slipped delivery schedules, due to the customary practice of following prototype weapon systems perilously close with production runs.

The next step in system design, following preparation of an OSD, is to proportion the allocation of functions between man and machine in order to arrive at a practical configuration. Specifically, it must be decided whether automatic sequencing should be employed, or whether primarily manual sequencing as shown in Fig. 1 is necessary to account for possible malfunctions or sudden changes in the tactical situation. In general, system design will aim for the greatest degree of automation consistent with reliability and practical bounds of equipment complexity. In a system as vital as an ALBM system, manual monitoring must be readily changeable to manual operation in the event of component malfunction. Although the scope of the OSD as shown encompasses only normal operation, other sequences naturally follow each decision hexagon. Other decisions and actions follow every indication *not* received. Separate OSD's are therefore necessary to describe such major malfunction sequences as missile bypass during normal launch or missile jettison in the event of a hazardous circuit alarm during normal cruise conditions. More detailed corrective actions for each possible malfunction can often be represented profitably in tabular form, the OSD's being reserved for system problems involving coordination among several stations.

The Operation Sequence Diagram technique provides a convenient method whereby system operation can be codified simultaneously with hardware design. The human engineer can lay out his panels realistically; the project engineer can obtain a better idea of the man-machine relationships for various degrees of automation, and can therefore evaluate alternative system designs. Perhaps most important of all, operating personnel can take a look at how a new system will operate, and provide useful feedback to the designers in time to effect essential hardware changes prior to system installation.