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# Functional Flow Diagrams: A New Tool For Engineering Management

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# FUNCTIONAL FLOW DIAGRAMS

## A NEW TOOL FOR ENGINEERING MANAGEMENT

Technical management, often done by "seat of the pants" during the airplane age, is becoming more systematized and sophisticated to meet the challenge of the space age. Man's presence in space means that there are now many more alternatives to accomplishing a function. Functional flow diagrams present the technical manager with a rapid, comprehensive way to evaluate all the alternatives and the consequences of his decisions on the rest of the system. They also provide him with a tool to check the system design to assure that all the requirements are satisfied. The latest techniques are typified in the Air Force System Command Manuals 375-1, 2, 3, 4, and 5. One of these, AFSCM 375-5, "System Engineering Management Procedures", describes specific system engineering methods to be followed by recipients of large Air Force contracts. This paper describes the preparation of functional flow diagrams which will be of value to both engineers and their technical managers. The illustrations are typical for a Manned Orbiting Laboratory (MOL) Program.

Functional flow diagrams were prepared on earlier programs, including Titan II and Titan III, and are one of the required products of AFSCM 375-5. Traditionally, these "old" flow diagrams take the form of sequences of functions needed to accomplish a desired operation or mission (see Figure 1). Such diagrams, even when carried out to a lower indenture (see Figure 2), are of limited value. They tend to lag the conceptual and design efforts.

The new type of functional flow diagram (see Figure 3) starts where the traditional type ended. Let us see how Figure 3 was developed, what it tells us, and how it can be used.

### Derivation

On the left side of Figure 1 in Zone 2B, is function 18 (Protect and Enclose Personnel and Equipment). Function 18 is then broken down to its lowest indenture on Figure 2. When such a breakdown is completed for each function of Figure 1, the "old style" functional flow diagrams are considered completed. Such diagrams are limited to serving as a partial basis for the preparation of functional requirements. Here is where the new flows begin.

New Flows - On Figure 2, we will follow one lower indenture path under Function 18 (Protect and Enclose Personnel and Equipment) to sub-function 18.3 (Protect Personnel and Equipment from Space Environment). Note that this sub-function is composed of three lower level functions: 18.3.1, 18.3.2, and 18.3.3. (Zones 3D and 4D)

Figure 3 begins with function 18.3.1 (Contain Pressure in Lab Vehicle Modules). Three normal conditions or major paths are considered. These lead to "Contain Pressure in Crew Module" (Zone 4D), "Contain Pressure in Mission Module" (Zone 4K), and "Protect Personnel and Equipment from Space Debris" (Zone 1I). If these conditions are achieved, we proceed to the numbered functions which follow. For instance, "Contain Pressure in Mission Module" must be in a "go" state, for functions 13, 19, 20, 22, 24, 28, 30, 31, 35, 36, 37, 38, 39, 40, and 44 to proceed.

For clarification, "Contain Pressure in Mission Module" is drawn separately on Figure 4. If "Contain Pressure in Mission Module" cannot be accomplished (pressure is falling), the alternate paths are shown going up from the "OR" gate 8C preceding "Contain Pressure in Mission Module." These paths are numbered 2, 3, 4, and 8.

Path 2 shows that a leak in the mission module is repaired (Zone 8D) and we return to the "go" condition (path 1).

Path 3 goes to an "AND" gate 6G (which indicates by path 13 that space suits have been removed for normal operation in a "shirtsleeve" environment) through "OR" gate 6K (on path 3) to "Evacuate Mission Module to Crew Module" (Zone 6M) to "Perform Limited Experiments in Crew Module" (Zone 6-0). Alternatively, from "OR" gate 6K, path 5 can be followed up to "OR" gate 1K, to "Enter Gemini B" (Zone 1M) to "ABORT" (Zone 1-0).

Path 4 goes to an "AND" gate 5C (path 12 indicates that space suits have been removed) which flows to "Don Space Suits" (Zone 5E) to "OR" gate 4J and then to either "Perform Limited Experiments in the Mission Module" (Zone 4M) or up on path 7 to "OR" gate 1K to "Enter Gemini B" (Zone 1M) via path 5 to "ABORT" (Zone 1-0).

Should there be a "Catastrophic Pressure Loss" (Zone 4B), path 8, we can go two ways after "OR" gate 4E. Going vertically up to "AND" gate 1E (which indicates by path 9 that space suits have been removed for normal operation in a "shirtsleeve" environment) the crew is lost (Zone 1B). Going horizontally to "AND" gate 4H (which indicates by path 10 that space suits have not been removed for normal operation in a "shirtsleeve" environment) on path 11 to "OR" gate 4I, "OR" gate 4J follows path 6 to "Perform Limited Experiments in the Mission Module" (Zone 4M) now unpressurized or, from "OR" gate 4I, via path 12 to "OR" gate 6K, then via path 3 to "Evacuate from Mission Module to Crew Module" (Zone 6M) to "Perform Limited Experiments in Crew Module" (Zone 6-0). Finally, we can proceed on path 5 from "OR" gate 6K (or on path 7 from "OR" gate 4J) through "OR" gate 1K to "Enter Gemini B" (Zone 1M) and "ABORT" (Zone 1-0).

In summary, the new style flow diagram is developed by considering all the alternates for both "go" and "no-go" situations. "Go" conditions that are prerequisites for each situation, the functions following, and what can be accomplished in case of a limited "go" situation, such as "Perform Limited Experiments in Crew Module" (Zone 3M, Figure 3), are all depicted.

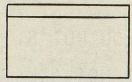
Uses - By supplying reliability numbers and performance time for each function on Figure 3, and making similar flow diagrams for every lowest level function which can be so treated (note that "Protect Personnel and Equipment from Space Debris", Zone 1-I, on Figure 3, cannot be so treated), you can:

1. Determine all conditions which could cause either loss of crew or mission abort and what is the probability of each happening.

2. By comparing the flow diagrams with the system requirements and hardware design, readily see both overdesign and design gaps.

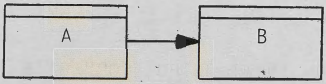
3. By breaking down the flows into a task analysis, and putting the result into a computer, generate maintenance information, support data needed, and spares back-up.

TABLE 1 FUNCTIONAL SYMBOLS

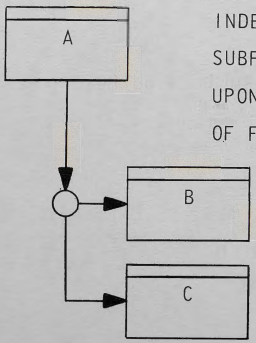


FUNCTION WHICH IS DEVELOPED ON THE PARTICULAR FLOW ON WHICH IT IS SHOWN.

REFERENCE FUNCTION, DEVELOPED TO A LOWER LEVEL ON ANOTHER FUNCTIONAL FLOW DIAGRAM.

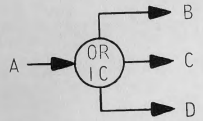



FUNCTION A IS COMPLETED BEFORE FUNCTION B IS STARTED.



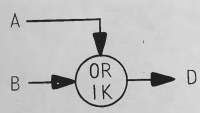

FUNCTIONS B AND C ARE LOWER LEVEL INDENTURES OF FUNCTION A. THEY ARE SUBFUNCTIONS OF FUNCTION A WHICH, UPON COMPLETION, INDICATES COMPLETION OF FUNCTION A.

TABLE 2 FLOW DIAGRAM LOGIC SYMBOLS (REF. FIG.4)




OUTPUT "OR" GATE

INPUT A RESULTS IN EITHER OUTPUT B, OUTPUT C, OR OUTPUT D; BUT NOT ALL THREE OR ANY TWO. THE 1C INDICATES THE ZONE ON FIGURE 4.

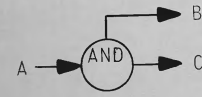



INPUT "OR" GATE

EITHER INPUT A OR B WILL RESULT IN OUTPUT D. NOT MORE THAN ANY ONE INPUT AT ONE TIME WILL BE PRESENT.


COMBINATION INPUT-OUTPUT "OR" GATE

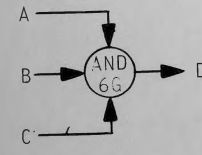
EITHER INPUT A OR B WILL RESULT IN EITHER OUTPUT C OR D. NO TWO INPUTS OR OUTPUTS ARE PRESENT AT ONE TIME.




OUTPUT "AND" GATE

INPUT A WILL RESULT IN OUTPUTS B & C.

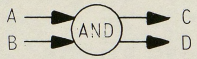
( NO EXAMPLES ON FIGURE 4. )




INPUT "AND" GATE

INPUTS A,B, & C MUST BE PRESENT TO OBTAIN OUTPUT D.

TABLE 2 (CONTINUED)



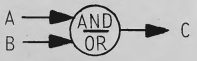

COMBINATION INPUT-OUTPUT "AND" GATE

BOTH INPUTS A AND B, WHEN PRESENT, WILL RESULT IN BOTH OUTPUTS C AND D. NO ONE INPUT WILL RESULT IN ANY OUTPUT; BOTH INPUTS PRESENT WILL NOT RESULT IN ONLY ONE OUTPUT.

( NO EXAMPLE IS INDICATED BECAUSE NONE WAS USED ON FIGURE 4. )

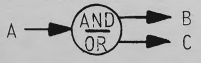

"NOT" GATE

THE ABSENCE OF INPUT A RESULTS IN OUTPUT B. NO EXAMPLE APPEARS ON FIGURE 4.




INPUT "AND/OR" GATE

EITHER INPUT A OR B OR BOTH INPUTS A AND B WILL RESULT IN OUTPUT C. EXAMPLES ON FIGURE 1, ZONE 2J.




OUTPUT "AND/OR" GATE

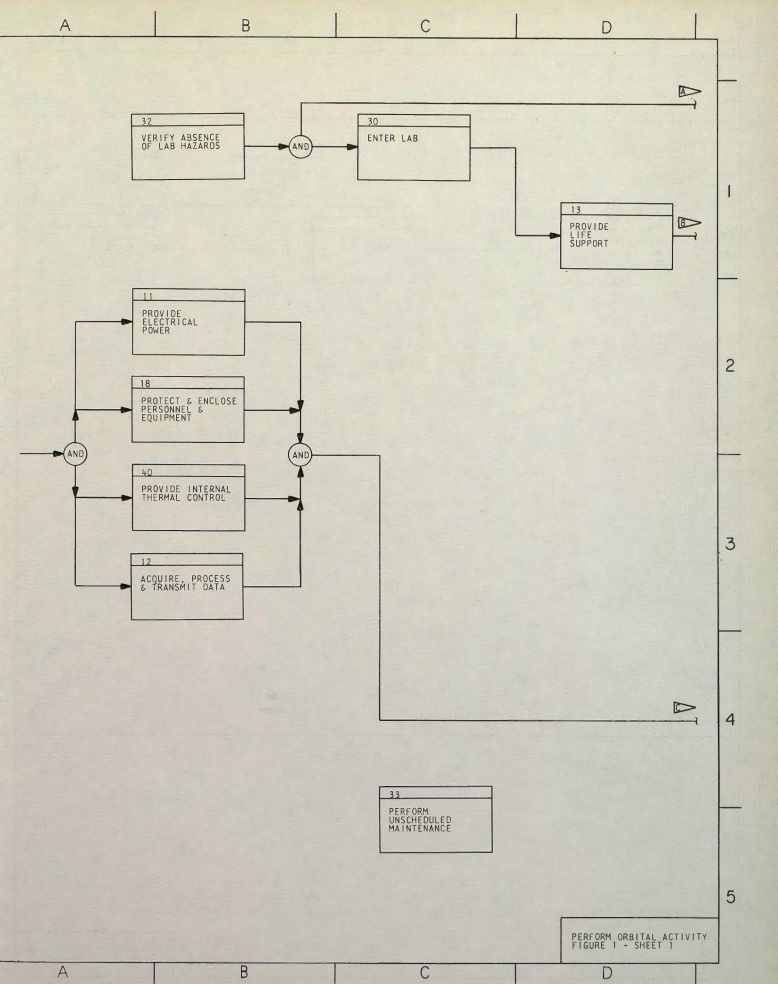
INPUT A WILL RESULT IN EITHER OUTPUT B OR OUTPUT C OR BOTH OUTPUTS B AND C. EXAMPLES ON FIGURE 1, ZONE 2J.

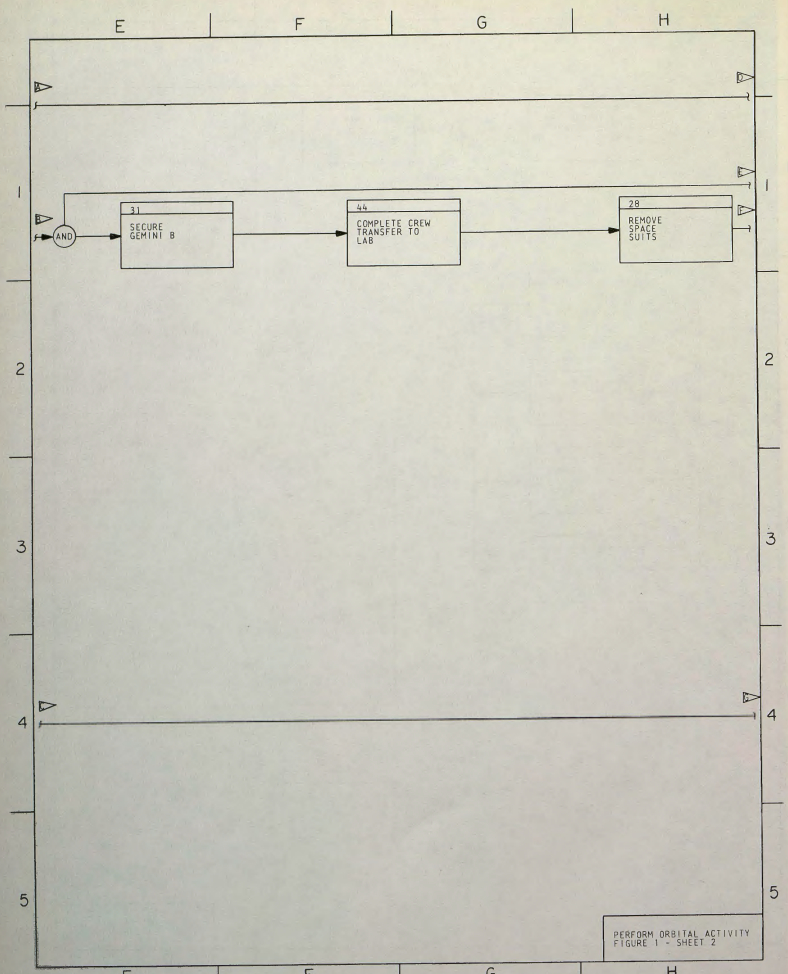
TABLE 3

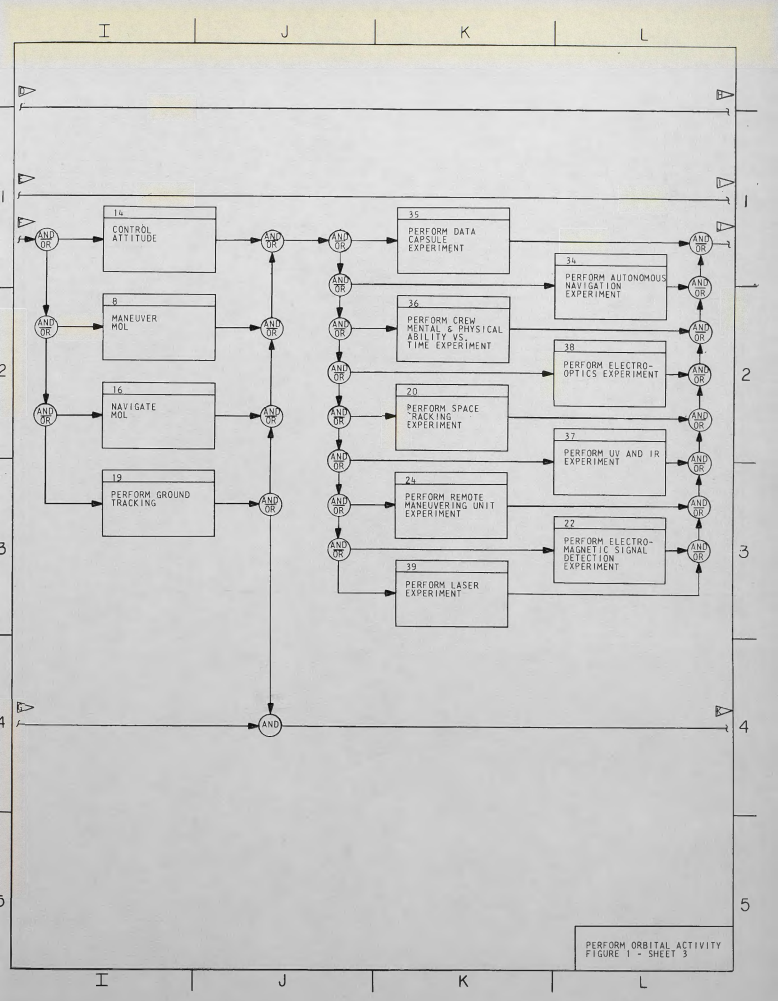
FUNCTIONS APPEARING ON FIGURE 1

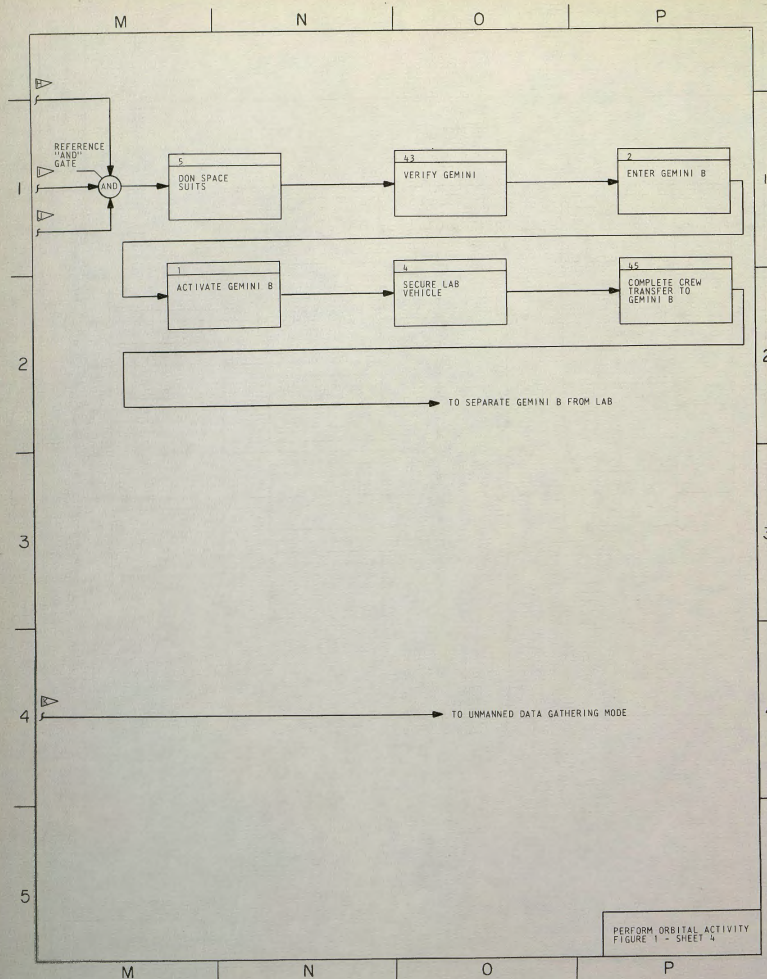
| Function* | Title | Zone |
|---|---|---|
| 1 | Activate Gemini B | 1Q |
| 2 | Enter Gemini B | 1P |
| 4 | Secure Lab Vehicle | 1R |
| 5 | Don Space Suits | 1M |
| 8 | Maneuver MOL | 2I |
| 11 | Provide Electrical Power | 2B |
| 12 | Acquire, Process, and Transmit Data | 3B |
| 13 | Provide Life Support | 1D |
| 14 | Control Attitude | 1I |
| 16 | Navigate MOL | 2I |
| 18 | Protect and Enclose Personnel and Equipment | 2B |
| 19 | Perform Ground Tracking | 3I |
| 20 | Perform Space Tracking Experiment | 2K |
| 22 | Perform Electromagnetic Signal Detection Experiments | 3L |
| 24 | Perform Remote Maneuvering Unit Experiment | 3K |
| 28 | Remove Space Suits | 1H |
| 30 | Enter Lab | 1C |
| 31 | Secure Gemini | 1E |
| 32 | Verify Absence of Lab Hazards | 1B |
| 33 | Perform Unscheduled Maintenance | 5C |
| 34 | Perform Autonomous Navigation Experiment | 2L |
| 35 | Perform Data Capsule Experiment | 1K |
| 36 | Perform Crew Mental and Physical Ability versus Time Experiment | 2K |
| 37 | Perform UV and IR Experiment | 4L |
| 39 | Perform Laser Experiment | 3K |
| 43 | Verify Gemini B | 1O |
| 44 | Complete Crew Transfer to Lab | 1F |
| 45 | Complete Crew Transfer to Gemini B | 1T |

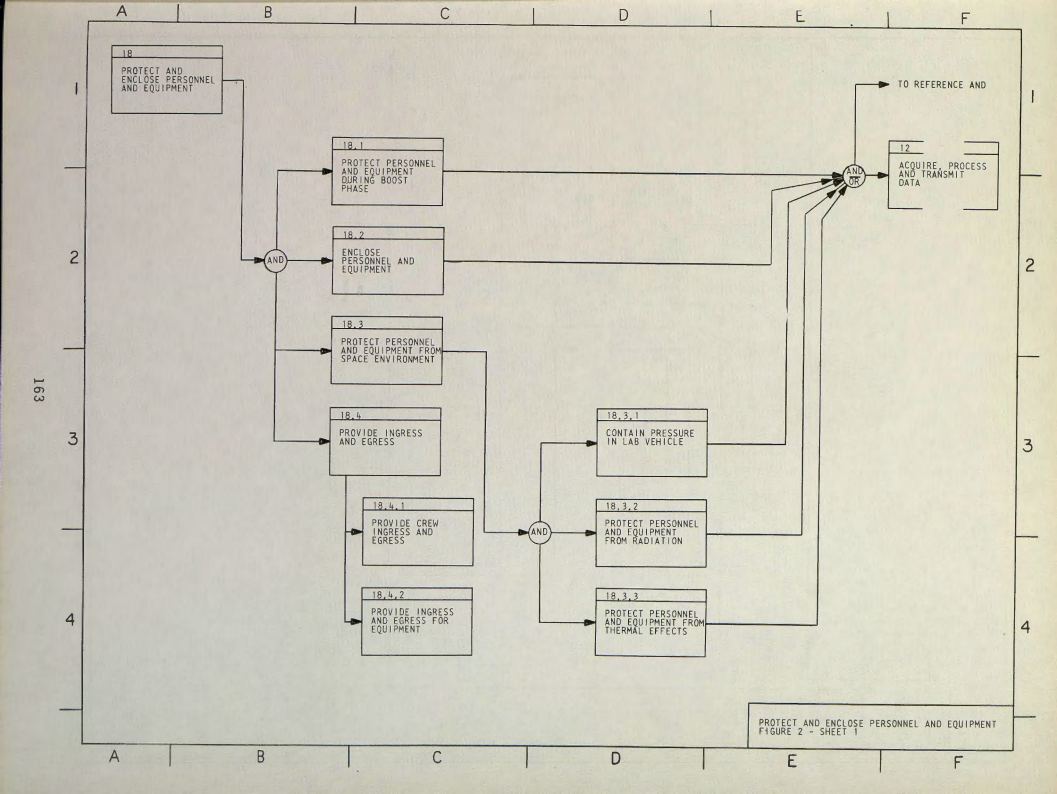
*Missing numbers indicate that some functions previously on Figure 1 were removed. When this is done, both function number and title are retired from further use.

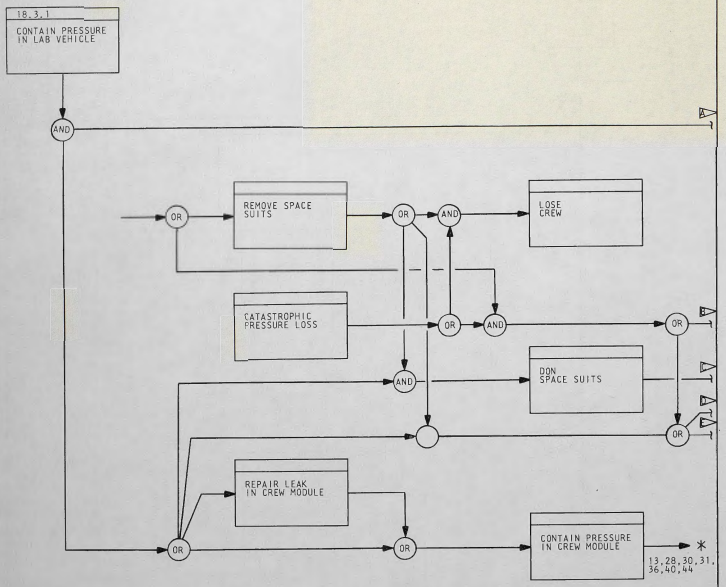

A
B
C
D
1
2
3
4
5
32
VERIFY ABSENCE OF LAB HAZARDS
AND
30
ENTER LAB
13
PROVIDE LIFE SUPPORT
11
PROVIDE ELECTRICAL POWER
18
PROTECT & ENCLOSE PERSONNEL & EQUIPMENT
AND
AND
40
PROVIDE INTERNAL THERMAL CONTROL
12
ACQUIRE, PROCESS & TRANSMIT DATA
33
PERFORM UNSCHEDULED MAINTENANCE
PERFORM ORBITAL ACTIVITY
FIGURE 1 - SHEET 1


E
F
G
H
1
2
3
4
5
AND
31
SECURE
GEMINI B
44
COMPLETE CREW
TRANSFER TO
LAB
28
REMOVE
SPACE
SUITS
PERFORM ORBITAL ACTIVITY
FIGURE 1 - SHEET 2


I
J
K
L
AND OR
14
CONTROL ATTITUDE
8
MANEUVER MOL
16
NAVIGATE MOL
19
PERFORM GROUND TRACKING
AND
35
PERFORM DATA CAPSULE EXPERIMENT
34
PERFORM AUTONOMOUS NAVIGATION EXPERIMENT
36
PERFORM CREW MENTAL & PHYSICAL ABILITY VS TIME EXPERIMENT
38
PERFORM ELECTRO-OPTICS EXPERIMENT
20
PERFORM SPACE TRACKING EXPERIMENT
37
PERFORM UV AND IR EXPERIMENT
24
PERFORM REMOTE MANEUVERING UNIT EXPERIMENT
22
PERFORM ELECTRO-MAGNETIC SIGNAL DETECTION EXPERIMENT
39
PERFORM LASER EXPERIMENT
PERFORM ORBITAL ACTIVITY
FIGURE 1 - SHEET 3

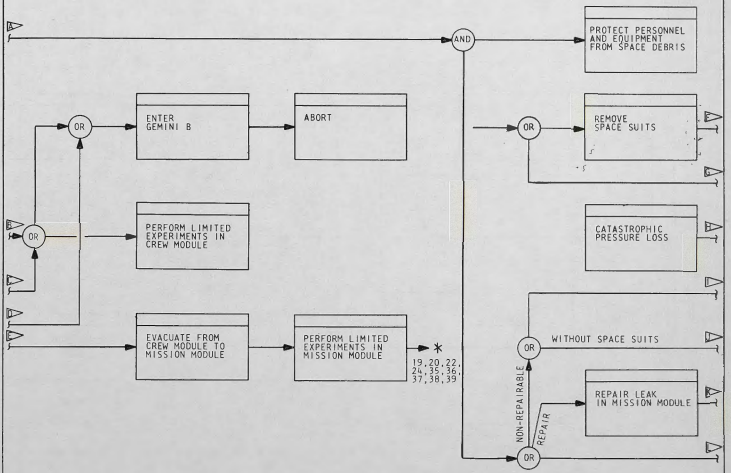

M
N
O
P
1
2
3
4
5
REFERENCE "AND" GATE
AND
5
DON SPACE SUITS
43
VERIFY GEMINI
2
ENTER GEMINI B
1
ACTIVATE GEMINI B
4
SECURE LAB VEHICLE
45
COMPLETE CREW TRANSFER TO GEMINI B
TO SEPARATE GEMINI B FROM LAB
TO UNMANNED DATA GATHERING MODE
PERFORM ORBITAL ACTIVITY
FIGURE 1 - SHEET 4


A
B
C
D
E
F
1
2
3
4
18
PROTECT AND ENCLOSE PERSONNEL AND EQUIPMENT
18.1
PROTECT PERSONNEL AND EQUIPMENT DURING BOOST PHASE
18.2
ENCLOSE PERSONNEL AND EQUIPMENT
18.3
PROTECT PERSONNEL AND EQUIPMENT FROM SPACE ENVIRONMENT
18.4
PROVIDE INGRESS AND EGRESS
18.4.1
PROVIDE CREW INGRESS AND EGRESS
18.4.2
PROVIDE INGRESS AND EGRESS FOR EQUIPMENT
AND
18.3.1
CONTAIN PRESSURE IN LAB VEHICLE
18.3.2
PROTECT PERSONNEL AND EQUIPMENT FROM RADIATION
18.3.3
PROTECT PERSONNEL AND EQUIPMENT FROM THERMAL EFFECTS
AND OR
TO REFERENCE AND
12
ACQUIRE, PROCESS AND TRANSMIT DATA
PROTECT AND ENCLOSE PERSONNEL AND EQUIPMENT
FIGURE 2 - SHEET 1



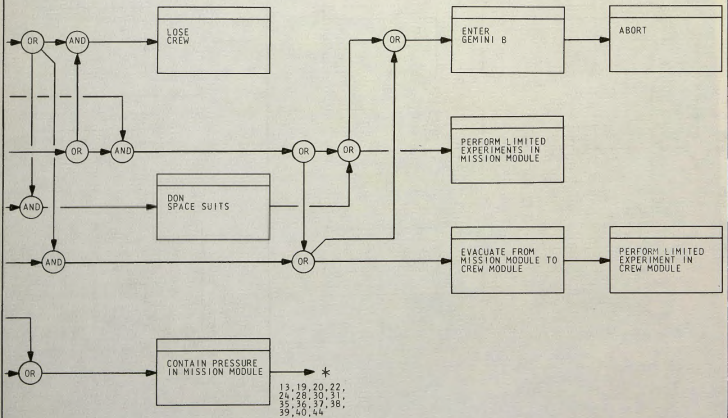

*FOR TITLES OF THESE FUNCTIONS, SEE FIGURE 1 AND TABLE 3

CONTAIN PRESSURE IN LAB VEHICLE
FIGURE 3 - SHEET 1



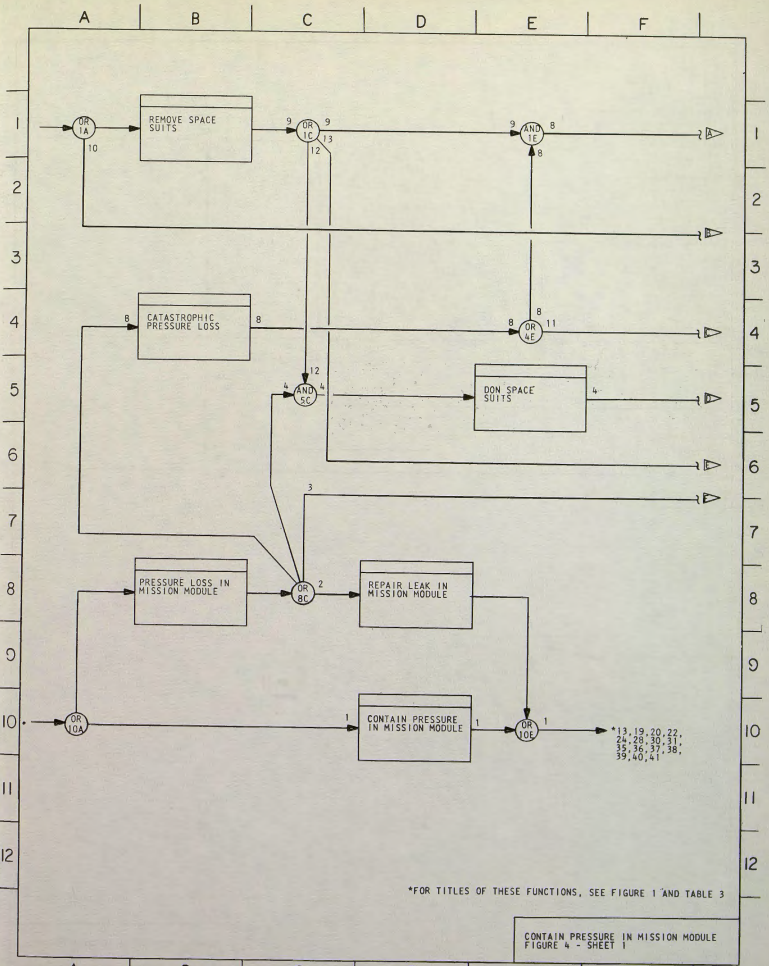

*FOR TITLES OF THESE FUNCTIONS, SEE FIGURE 1 AND TABLE 3

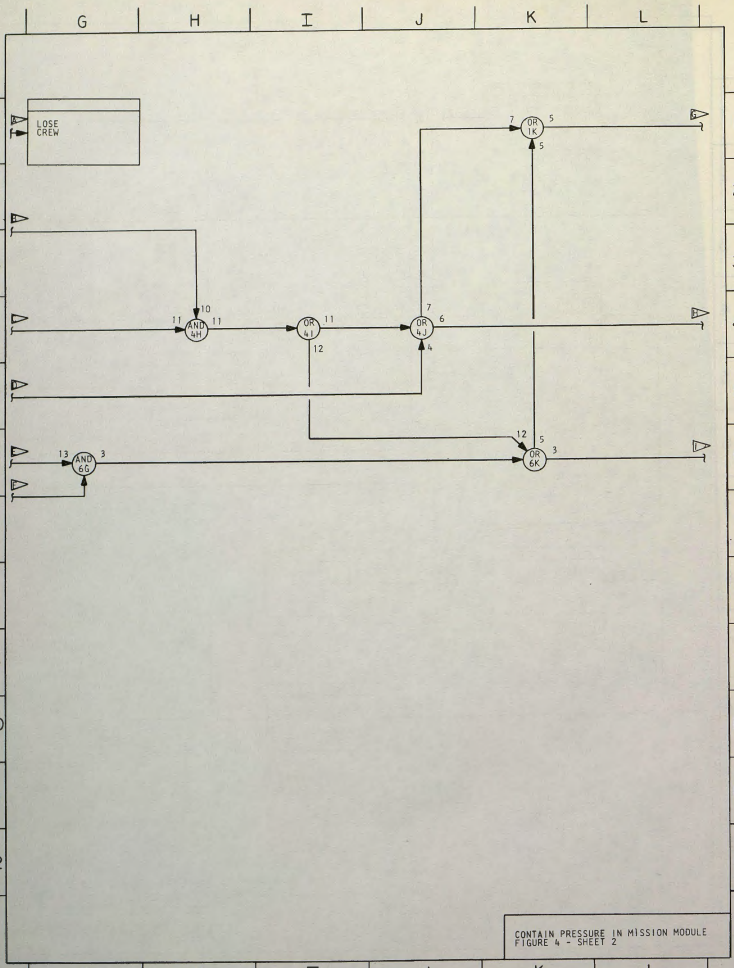
CONTAIN PRESSURE IN LAB VEHICLE
FIGURE 3 - SHEET 2

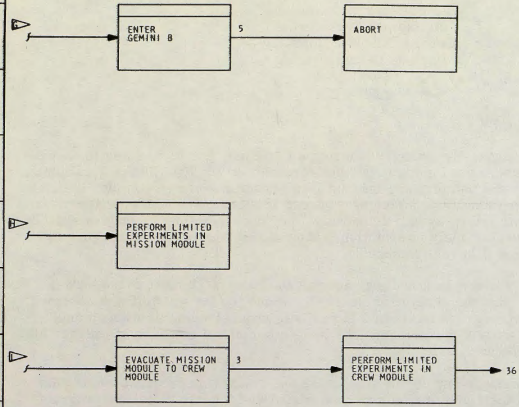



*FOR TITLES OF THESE FUNCTIONS, SEE FIGURE 1 AND TABLE 3

CONTAIN PRESSURE IN LAB VEHICLE
FIGURE 3 - SHEET 3


A
B
C
D
E
F
1
2
3
4
5
6
7
8
9
10
11
12
OR 1A
REMOVE SPACE SUITS
OR 1C
AND 1E
CATASTROPHIC PRESSURE LOSS
OR 4E
AND 5C
DON SPACE SUITS
PRESSURE LOSS IN MISSION MODULE
OR 8C
REPAIR LEAK IN MISSION MODULE
OR 10A
CONTAIN PRESSURE IN MISSION MODULE
OR 10E
*13,19,20,22; 24,28,30,31; 35,36,37,38; 39,40,41
*FOR TITLES OF THESE FUNCTIONS, SEE FIGURE 1 AND TABLE 3
CONTAIN PRESSURE IN MISSION MODULE
FIGURE 4 - SHEET 1


G
H
I
J
K
L
1
2
3
4
5
6
7
8
9
10
11
12
LOSE CREW
AND 44
OR 41
OR 43
OR 1K
OR 6K
AND 60
CONTAIN PRESSURE IN MISSION MODULE
FIGURE 4 - SHEET 2




CONTAIN PRESSURE IN MISSION MODULE
FIGURE 4 - SHEET 3